ID: S005 **PI: Marie Wingyee Lau** **Inst.: Kast** **Req.: 3 nights**

Spectral Evolution of Tidal Disruption Event Candidates

1 Scientific Justification

Tidal disruption event (TDE) of stars by supermassive black holes have been detected using UV/optical, soft X-ray, hard X-ray and radio telescopes (Komossa & Bade 1999; Gezari et al. 2009; Bloom et al. 2011; Cenko et al. 2012; Burrows et. al. 2011; Zauderer et. al. 2011). The best environments for TDE observations are galaxies with no previous accreting activities. When a star is tidally disrupted, about half the stellar mass accretes onto the supermassive black hole. The center of galaxy can brighten to Eddington luminosity in timescale of $\sim$ 1 month, and after the peak the light curve decays in a power law with time as $\propto t^{-5/3}$ and the luminosity goes to sub-Eddington in timescale of years (Rees 1988; Guillonchon & Ramirez-Ruiz et al. 2013).

It is puzzling that TDEs detected by telescopes in different wavebands seem to exhibit different properties. Soft X-ray detected TDEs, such as in Komossa et. al. 2008 and Wang et. al. 2012, showed extremely strong transient coronal lines from Fe X up to Fe XIV and broad emission lines. One UV/optical detected TDE candidate, PS1-10jh, demonstrated spectroscopic signature of He II but not the H II Balmer series or He I (Gezari et al. 2012). This can be explained if the disrupted star is a helium-rich stellar core whose shell has previously been stripped by the massive black hole, while another model predicts that even the disruption of a main sequence star can lead to only He II broad emission lines to be observed due to the limited size of the TDE accretion disk (Guillochon et al. 2013). Another UV/optical TDE revealed a pair of transient broad absorption features in the UV (Chornock et al 2014).

In addition to 30–40 TDE candidates detected for their accretion luminosity, two more TDEs have also been observed in hard X-rays by Swift for their jets (Burrows et al. 2011; Bloomeet et al. 2011; Cenko et al. 2012). No accompanying UV/optical powers were reported, possibly due to dust obscuration. One candidate, Swift J1644+57, has stopped emitting X-rays in $\sim$ 1.5 years since detection, suggesting the jet power has greatly declined or ceased, possibly due to a decrease in mass accretion rate and the change of state from a thick disk to a thin disk (Tchekhovskoy et al. 2014). If this model is correct, in several years, after the mass accretion rate drops to $\sim$ 1% of Eddington, the disk will become radiatively inefficient and a jet could be triggered again.

To further characterize the complex and transient nature of TDEs, we propose follow up observations of these objects at higher spectral resolution using the Lick/Kast. The galaxies that already showed transient optical emission lines, discovered with SDSS, will continue to show changes (high-ion lines weakening, low-ion lines strengthening) as the 'flare' travels though the galaxy core. Those galaxies that showed LINER or H II -like optical spectra contain more gas, and would show emission lines after the appropriate light travel time delay. The alaxies that lacked any emission-line might reprocess some of the flare radiation if they contain significant gas clumps/ISM. Also if a jet is triggered in some of the TDEs as accretion rate drops after a few years, we might also observe optical signatures related to jets.

The data taken with Lick/Kast of each target will be analyzed to 1. check if luminosity changes as power law with time to confirm whether the target is a real TDE; 2. check for any overall blueward shift in the continuum emission which comes from the disk; and 3. compare with spectra previously taken or data in the literature to build disk evolution models (Figure 1). This study will address how the accretion disk and its observables evolve in TDEs, which also helps to understand the general AGN/X-ray binary accretion disk evolutions. This study will also help to probe the environment of the centers of quiescent galaxies, which is otherwise difficult to observe. Finally, this study can help improve future TDE selection criteria, which is extremely important for the upcoming LSST survey in which ~ 2000 TDEs (Strubbe & Quataert 2009) are predicted to be observed.

References

Bloom J. S., Giannios D., Metzger B. D., et al., 2011, Science, 333, 203

Burrows D. N., et al., 2011, Nature, 476, 421

Cenko S. B., Krimm H. A., Horesh A., et al., 2012, ApJ, 753, 77

Chornock, R., Berger, E., Gezari, S., et al., 2014, ApJ, 780, 44

Gezari S., Heckman T., Cenko S. B., et al., 2009, ApJ, 698, 1367

Gezari, S., Chornock, R., Rest, A., et al., 2012, Nature, 485, 217

Guillochon, J., & Ramirez-Ruiz, E., 2013, ApJ, 767, 25

Guillochon, J., Manukian, H., & Ramirez-Ruiz, E., 2014, ApJ, 783, 23

Komossa S., Bade N., 1999, A&A, 343, 775

Rees M. J., 1988, Nature, 333, 523

Strubbe L. E., Quataert E., 2009, MNRAS, 400, 2070

Tchekhovskoy, A., Metzger, B. D., Giannios, D., et al, 2014, MNRAS, 437, 2744

Wang, T.-G., Zhou, H.-Y., Komossa, S., et al., 2012, ApJ, 749, 115

Zauderer B. A., Berger E., Soderberg A. M., et al., 2011, Nature, 476, 425

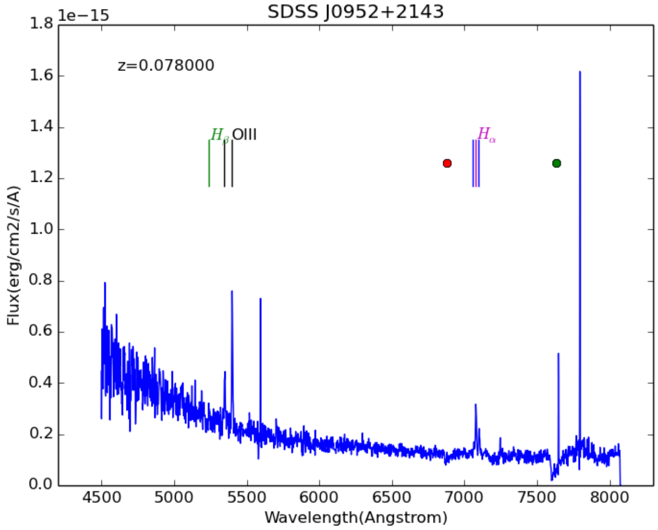

Figure 1: Fluxed preliminary spectrum of TDE candidate SDSSJ0952, taken by Co-I Dai with the Irénée du Pont Telescope and the Boller & Chivens Spectrograph on May 6, 2014. Although this galaxy showed a possible TDE outburst in 2005, broad H α emission line can still be observed after ~ 10 years, while H β emission has disappeared.

2 Technical Remarks

2.1 Progress Report

This is a new program.

2.2 Targets and Exposures

We will use the Shane 3 m telescope and the Kast spectrograph to observe a sample of ~ 20 known TDEs and TDE candidates. Since the interesting spectral features are very blue, dark runs are necessary. In order to resolve the narrow components of the emission lines (Figure 1), we maximize spectral resolution over wavelength coverage. Specifically we will use the 830/3460 on the blue side, the D45 dichroic and the 1200/5000 grating on the red side.

The SDSS r-band magnitudes for our targets range between 15 to 20. Our science goal will require ~ 3600 s of exposure to obtain sufficient signal-to-noise. Long exposures will be broken into 1800 s exposures as a compromise between CCD read noise and cosmic ray accumulation. With overhead, we expect we can observe ~ 7 targets per night. To observe a total of ~ 20 targets we request 3 nights. We prefer the dark time in January and May when all of our highest priority targets are within the telescope pointing limit.

Our highest priority targets are TDEs with prior transient emission lines. Second priority targets are gas rich hosts. Third priority targets have no prior emission lines and may have contamination from a nearby galaxy. Table 1 lists all the targets observable in semester 2015A.

2.3 Backup Program

In poor observing conditions we will increase exposure times on targets of highest priority (those with previously observed emission lines) or give preference to targets bright in the optical.

2.4 Status of Previously Approved 3-m Programs

Lau is a graduate student of J. Xavier Prochaska, who has numerous approved 3-m programs including a campaign for He II sources drawn from Pan-STARRS imaging in 2013A, which formed the basis of their Cycle 22 HST submission.

Table 1: List of targets.

Name	RA (J2000)	Dec (J2000)	r	z	Exposure	Notes
			Priority 1			
IC3599	12:37:41.12	+26:42:27.2	14.9	0.0212	900 s	Seyfert 1 features
PTF09ge	14:57:03.10	+49:36:40.8	17.2	0.064	3600 s	No H emission
PTF09djl	16:33:55.97	+30:14:16.7	19.7	0.184	7200 s	
SDSSJ0748	07:48:20.67	+47:12:14.3	17.1	0.0615	3600 s	
SDSSJ0938	09:38:01.64	+13:53:17.0	16.6	0.1006	1800 s	
SDSSJ1055	10:55:26.41	+56:37:13.1	17.2	0.0743	3600 s	
SDSSJ1241	12:41:34.25	+44:26:39.2	15.9	0.0419	1800 s	
SDSSJ1342	13:42:44.41	+05:30:56.1	16.7	0.0366	1800 s	
SDSSJ1350	13:50:01.49	+29:16:09.7	17.6	0.0777	3600 s	
VV-2	23:23:48.61	-01:08:10.3	19.6	0.2515	7200 s	
			Priority 2			
ASASSN-14ae	11:08:40.11	+34:05:52.2	16.7	0.0436	1800 s	Exponential decay
D23H-1	23:31:59.53	+00:17:14.5	19.3	0.1855	5400 s	Star forming host
NGC5905	15:15:23.32	+55:31:01.6	12.2	0.01124	600 s	
PTF10iya	14:38:40.98	+37:39:33.4	20.0	0.22405	7200 s	
			Priority 3			
NGC3599	11:15:29.95	+18:06:37.3	12.2	0.00270	600 s	LLAGN features
RXJ1420+53	14:20:24.36	+53:34:11.7	19.8	0.147	7200 s	Galaxy nearby
SDSSJ1201	12:01:36.02	+30:03:05.2	17.9	0.146	3600 s	
SDSSJ1323	J13:23:41.97	+48:27:01.2	17.5	0.0875	3600 s	No features
VV-1	23:42:01.40	+01:06:29.2	19.3	0.136	5400 s	

2.5 Supplementary Observations

Co-I Dai has taken direct images and spectra of SDSSJ0938, SDSSJ0952, SDSSJ1342 and RXJ1242-11A using the 2.5 m Irénée du Pont Telescope. The WFCCD was used for direct imaging and the Boller & Chivens Spectrograph was used for spectroscopy.

2.6 Technical Concerns

We have none.

2.7 Experience and Publications

PI Lau has extensive experience with Kast both on site and remotely. Co-I Dai, Guillochon and Ramirez-Ruiz are experts in the theory of tidal disruption events.