Slim Disk Lights TDE

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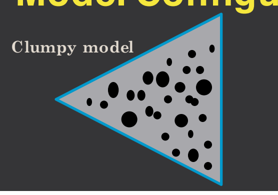
Fuguo Xie, Doosoo Yoon (SHAO), Xiaodi Yu (XMU), Xiang Pan (PRIC), Maochun Wu, Xinyue Shi, Zhicheng He, Zhenfeng Sheng, Chenwei Yang (USTC)

Abstract

Tidal disruption event (TDE) provides unique opportunity to examine the dynamics of outflows from the accretion disk around the central super-massive black hole because the part of accreted gas from the TDE is ejected with some opening angle. Based on Slim Disk model at which the disk is geometrically thick and radiatively inefficient, we generate outflowing wind launched from ~50 R_{sh}. Using the observed Spectral Energy Distribution (SED) as an ionization source, we calculate the main optical emission line strength of the wind with CLOUDY and compare that with observed data from 20 to 100 days after outburst. In the first order approximation, we found that our best model which fits to the observation has a wind launching speed of > 5000 km/s to reach 10^{14} cm and a clump density of ~$10^{10\sim12}$cm^{-3}. This result shows that the observed optical TDE candidates can be explained by fast outflows from the gas accreted into Slim disk.

Model Configuration



Slim accretion theory provides mass outflow rate $\dot{M}_{out}$ from $\dot{M}_{in}$

$$\dot{M}_{\rm out} = 4\pi\, C\, R^2\, V_r^2\, \rho$$

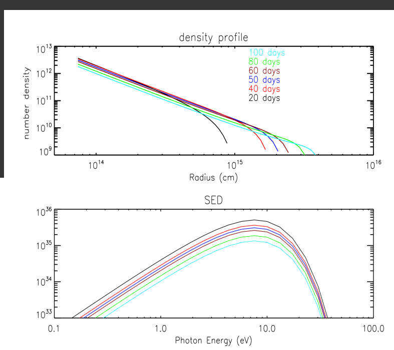
C = space covering fac

$V_r \approx$ const., $0.1 - 0.3\; V_{\rm Kep}(R_{\rm Tide})$

$\rho_{\rm clumps} \approx 100\,\rho$

$f \approx 1/100$, volumn filling factor

$\Delta R_{\rm clumps} \approx 5 - 10 R_s$



The center black hole mass is 10^8 $M_\odot$ and the disrupted star is a solar type star. The evolution of accretion rate is based on analytic model from Lodato et al.2009. The outflow rate is 80% of the inflow rate and launched from 4R_T (~10^{13}cm, roughly the outer radius of TDE accretion disk) with a constant speed of 5000 km s^{-1}. We use a clumpy model with filling factor of 1%. The SED striking the clouds is a blackbody with constant temperature of $10^{4.5}$ K and the luminosity declines with time as 10^{10}exp(-t/60) $L_\odot$ (Holoien et al.2016).

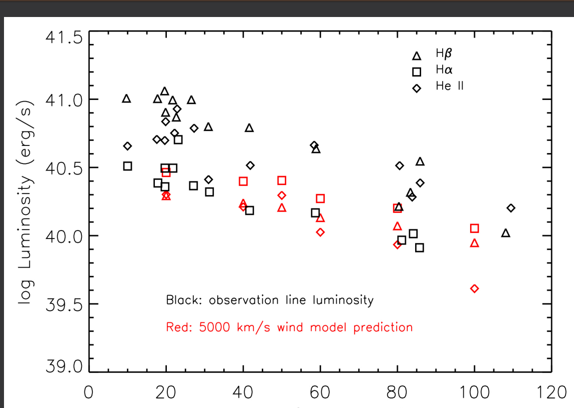


Fig3. The logarithmic scale of luminosity as a function of evolution time. The black symbols represent observed luminosity of the hydrogen lines at ASASSN-14li (Holoien et al.2016), and the red symbols represented the predicted luminosity which was calculated with our fiducial model (above) by using CLOUDY.

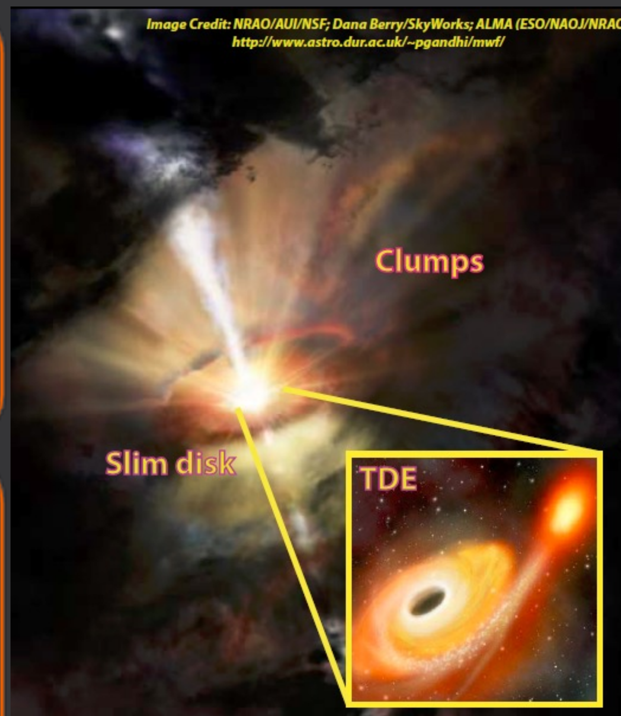


Fig1. Conceptual sketch of outflows from slim disk when the tidally disrupted materials fall into the central black hole. The outflowing gas can cool down to form cold clumps.

Fig2. Upper panel: Temporal evolution of density profile from the wind-launching point. Bottom panel: Spectral energy distribution from the hot accretion disk illuminating the interstellar medium.

Discussion & Conclusion

The fiducial model could produce similar recombination line luminosities and decline trends as observation. We also try lower launching speed (1000km s^{-1}) model and continuous gas model (filling factor~100%), the resultant line luminosities are 2 orders lower than observation due to gas over-ionization problem and large optical depth of recombination lines. The filling factor strongly affects the result since it affects the density and line luminosities are proportional to density square. Our result shows that the observed optical TDE candidates can be explained by fast outflows from the gas accreted into Slim disk.

Caveats & Future Work

Our simplified model only consider outflowing gas with filling factor of 1% and constant speed of 5000 km s-1 and ignores the substructure and dynamics of the clouds (e.g. the clouds may have size and density distributions which will affect the radiation transfer process, and radiation pressure is also important in super-Eddington accretion process). We will derive a more reality-based calculation from hydrodynamic simulations(Ohsuga et al.2014).

Reference:

Holoien T. W.-S et al.2016, MNRAS.455.2918H

Lodato G., King A. R., Pringle J. E., 2009, MNRAS, 392, 332

Ohsuga Ken, Mineshige Shin, 2014, SSRv.183.353O