Hard X-ray Luminosity Function of Tidal Disruption Events: First Results from MAXI Extragalactic Survey

MAXI 7 years @ RIKEN, 6 December 2016

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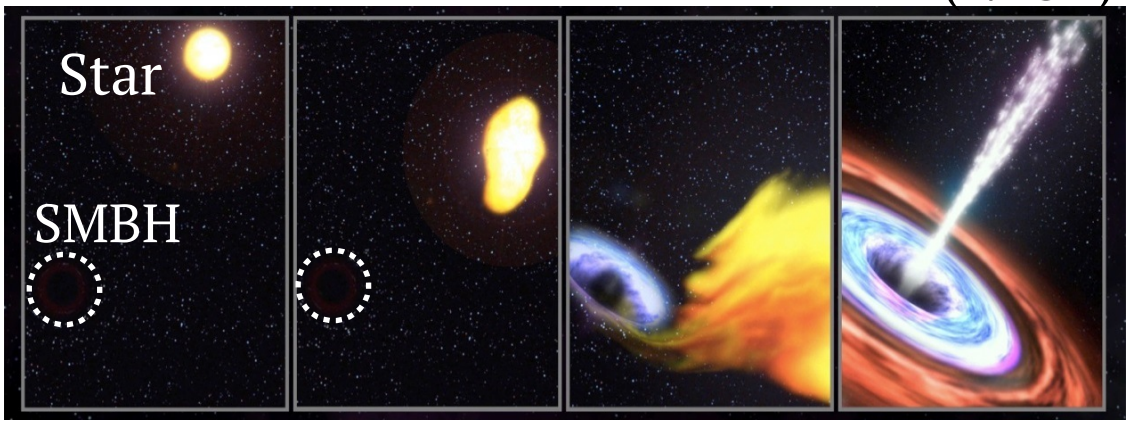
Tidal Disruption Events (TDEs)

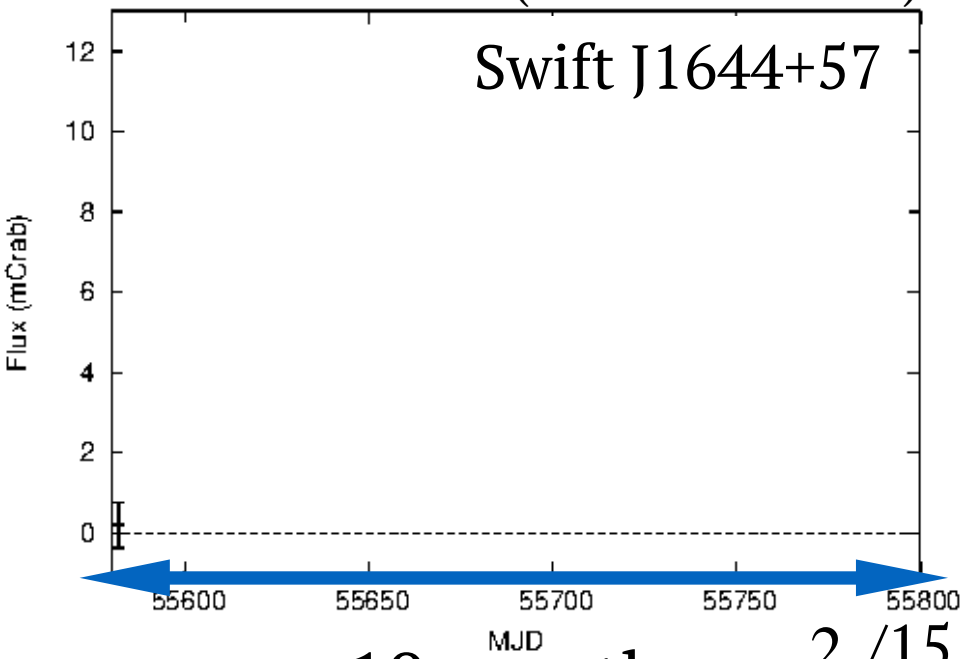
- A star is disrupted by a Supermassive Black hole (SMBH) when the star falls inside the tidal disruption radius (r_T).
- The SMBHs ($M_{BH} > 10^8 M_{sun}$) will not cause the TDEs due to $r_T < r_{sch}$ for stars lighter than the solar mass.
- The luminosity suddenly rises and follows power-law decay, of which index is ~ -5/3 (Phinney 1989).

$$r_T \sim R_* * (M_{BH}/M_*)^{1/3}$$

(NASA)



(in 4-10 keV band)



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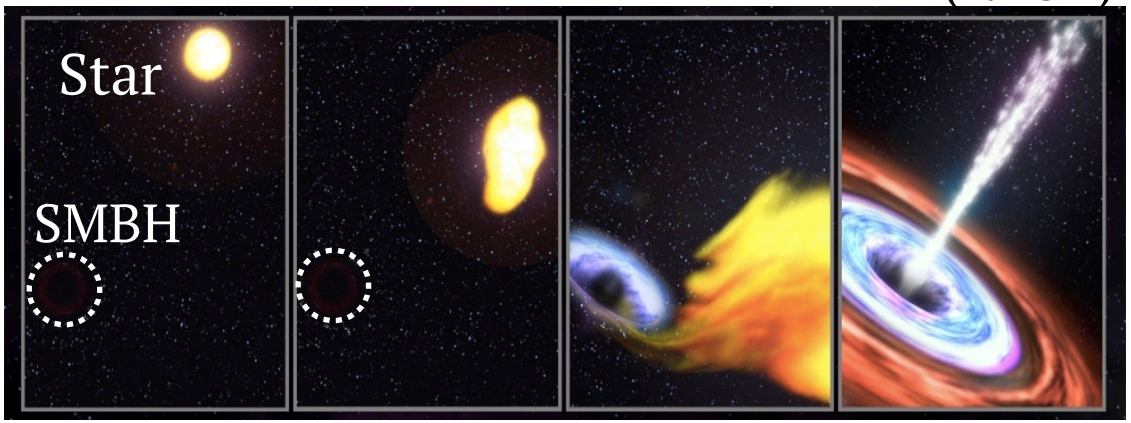

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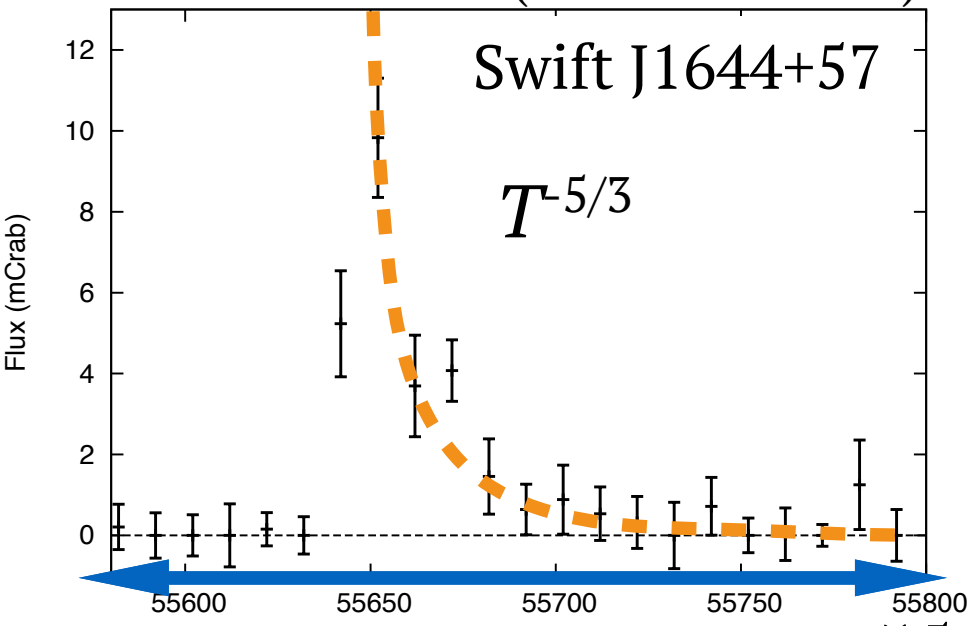

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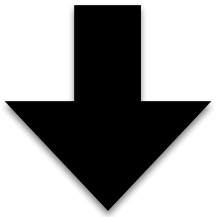
Main Topic

- Derivation of TDE Luminosity function (= LF, $\mathrm{Mpc^{-3}log}\,L^{-1}\mathrm{yr^{-1}}$), where L is "*peak*" luminosity.

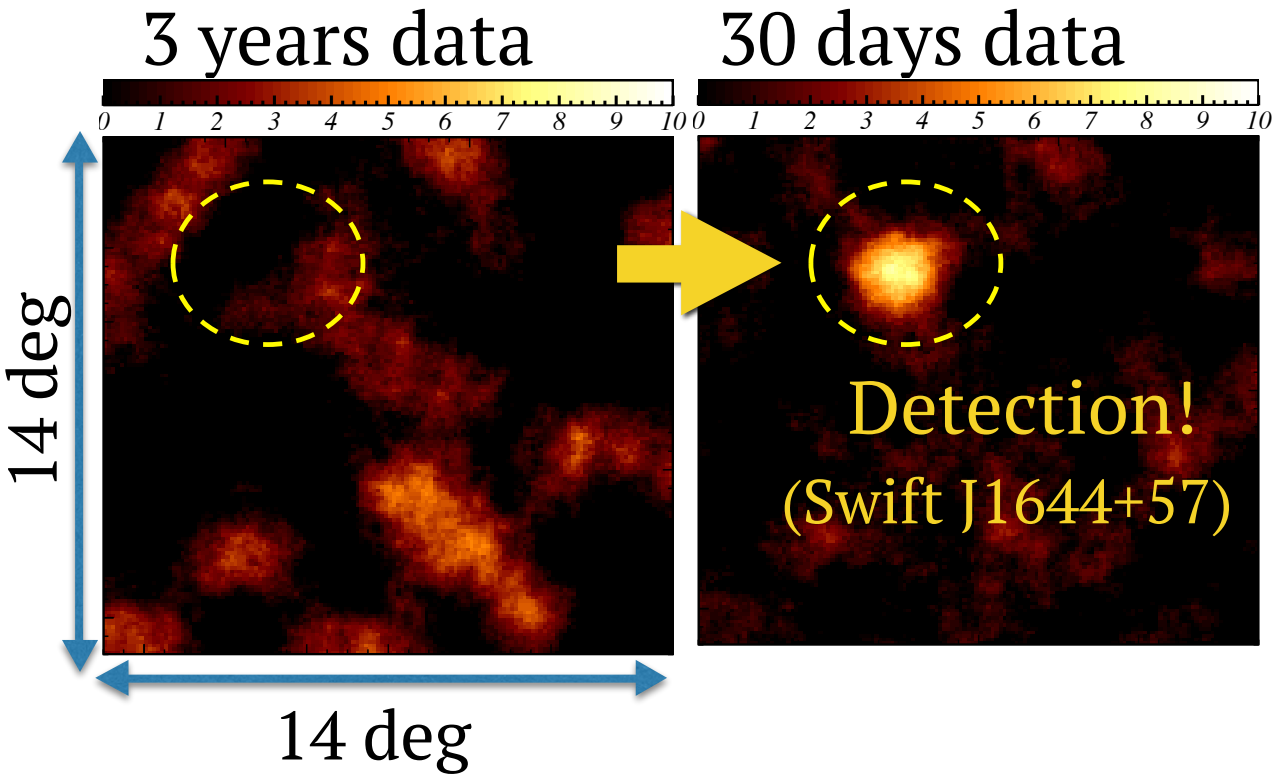


From the LF, we can know ..

- Effect on the SMBH mass growth history.
- Prediction of TDE number detected by a given observatory in the future.

Detection of TDEs with MAXI

- All-sky survey with MAXI is highly useful to detect transient TDEs
- We analyzed the all-sky data obtained every 30/90 days to search for transient events, such as TDEs (2009/09-2012/10).



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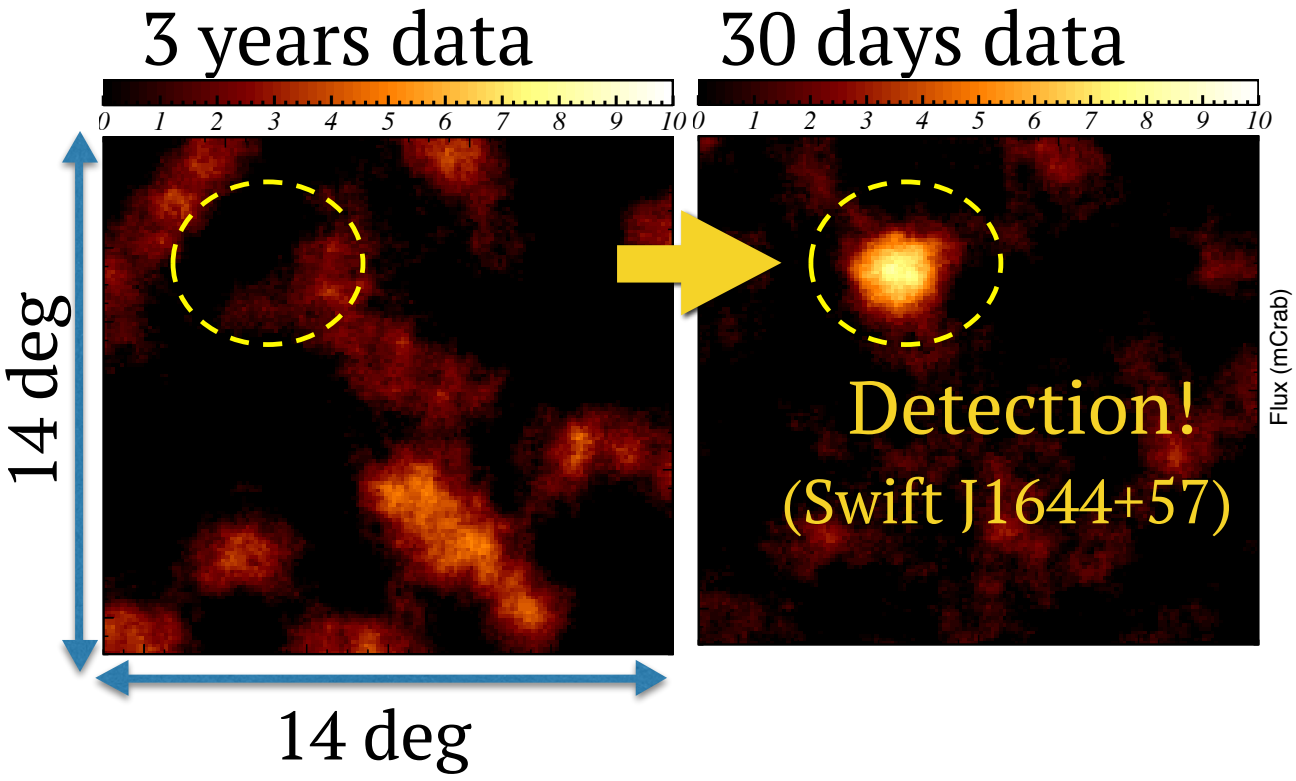
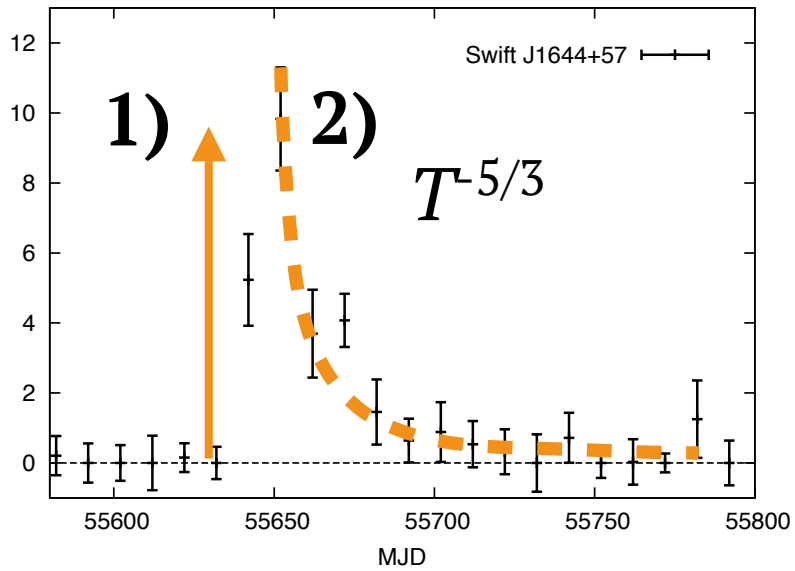
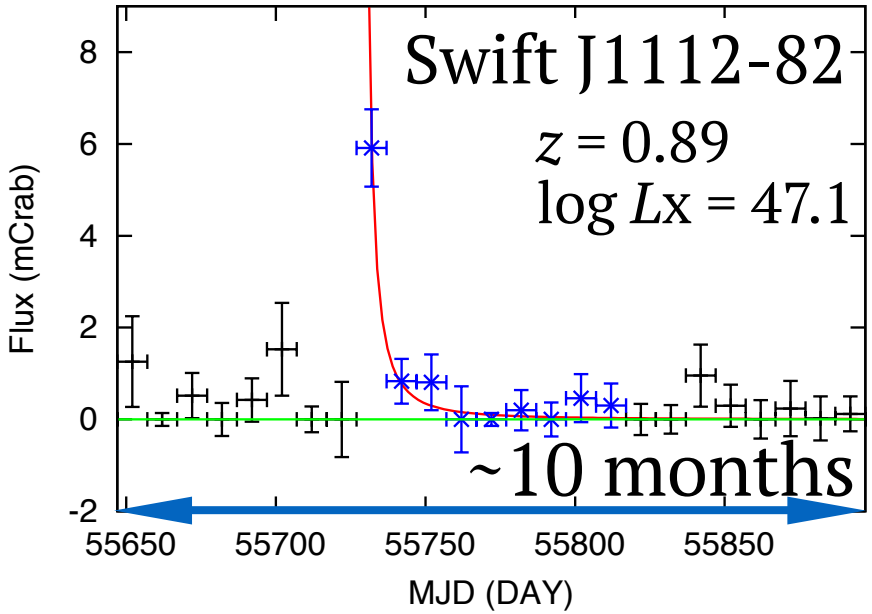
- We adopted the two criteria of "**1)** high amplitude" and "**2)** -5/3 power-law decay of light curve" to identify TDEs.

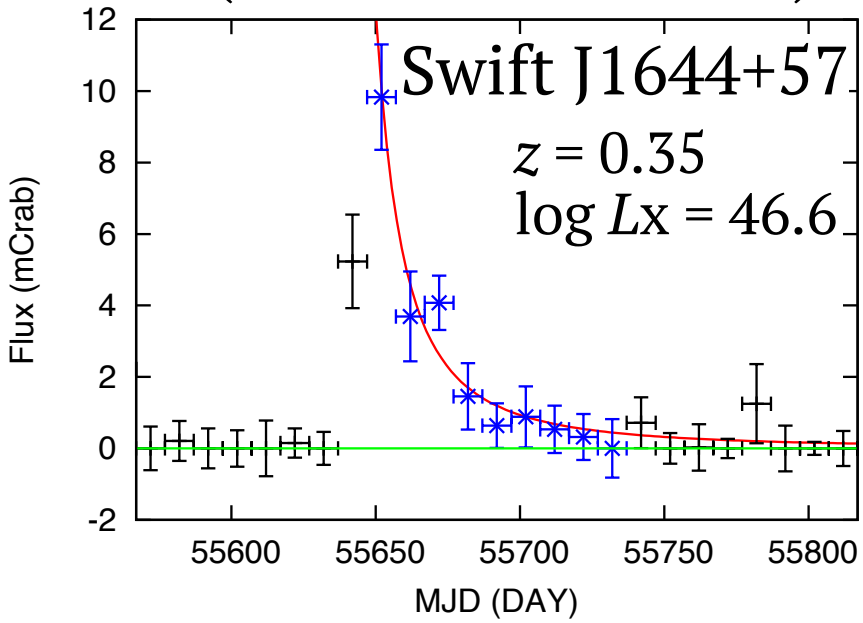


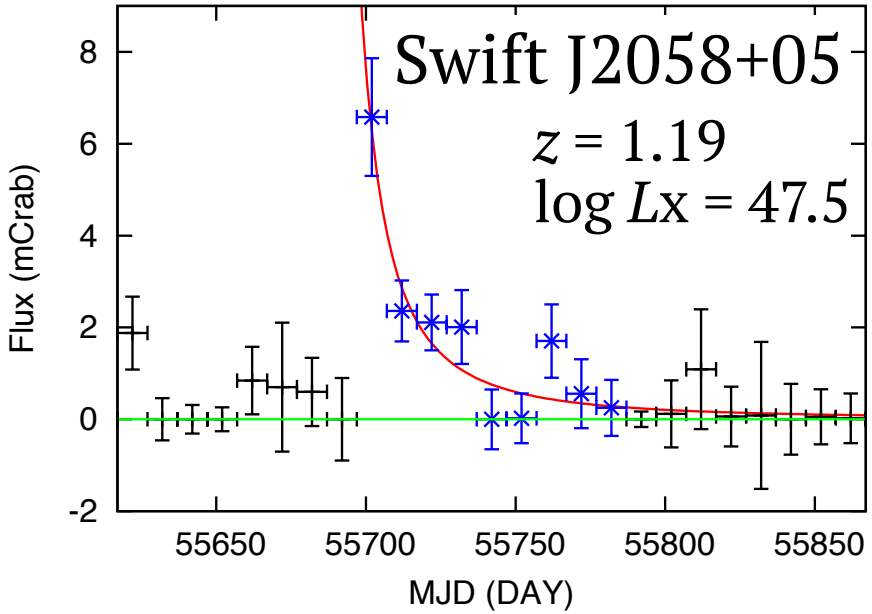


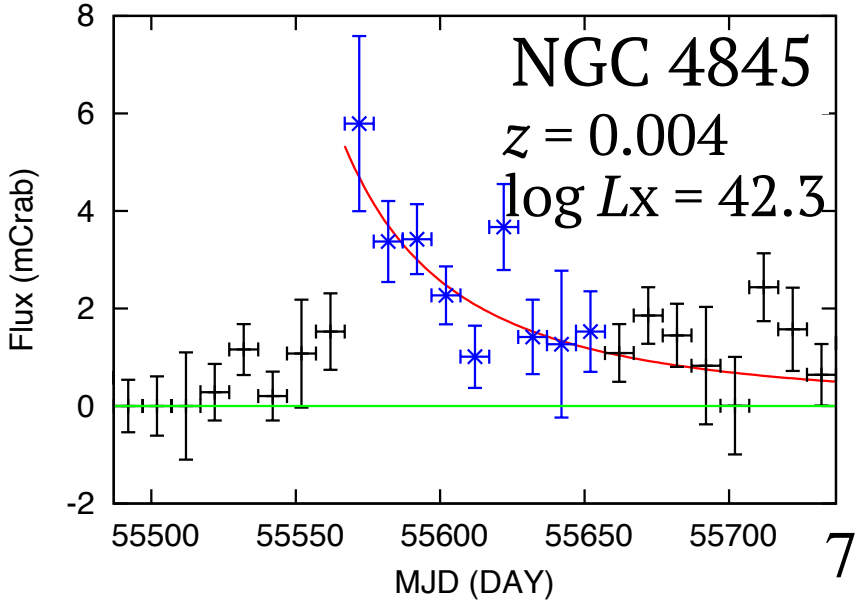
X-ray Survey for TDEs

Four TDE candidates are found (2009/09-2012/10)









Model of TDE LF

- LF is first based on SMBH mass function ($\mathrm{Mpc^{-3}M_{BH}^{-1}}$)

$$\psi(M_{\mathrm{BH}*}; M_{\mathrm{BH}})\mathrm{d}M_{\mathrm{BH}} = \psi_0 \left(\frac{M_{\mathrm{BH}}}{M_{\mathrm{BH}*}}\right)^{\gamma} e^{-(\frac{M_{\mathrm{BH}}}{M_{\mathrm{BH}*}})^{k}} \frac{\mathrm{d}M_{\mathrm{BH}}}{M_{\mathrm{BH}*}} \quad (\gamma = -1.24, k = 0.8)$$

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- The BH mass dependence of the TDE rate ($\mathrm{yr^{-1}}$; Stone+14).

$$\xi \propto M_{\mathrm{BH}}^{\lambda} \quad (\lambda = -0.4)$$

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- Assume that the "*peak*" luminosity is proportional to the Eddington luminosity. → LF ($\mathrm{Mpc^{-3}yr^{-1}}L^{-1}$)

$$\frac{\mathrm{d}\Phi(L_{\rm X},z)}{\mathrm{d}L_{\rm X}}\mathrm{d}L=(1+z)^{p}\psi_0\xi_0\left(\frac{L_{\rm X}}{L_{\rm X*}}\right)^{\gamma+\lambda}e^{-(\frac{L_{\rm X}}{L_{\rm X*}})^{k}}\frac{\mathrm{d}L_{\rm X}}{L_{\rm X*}}$$

Redshift evolution is also considered.

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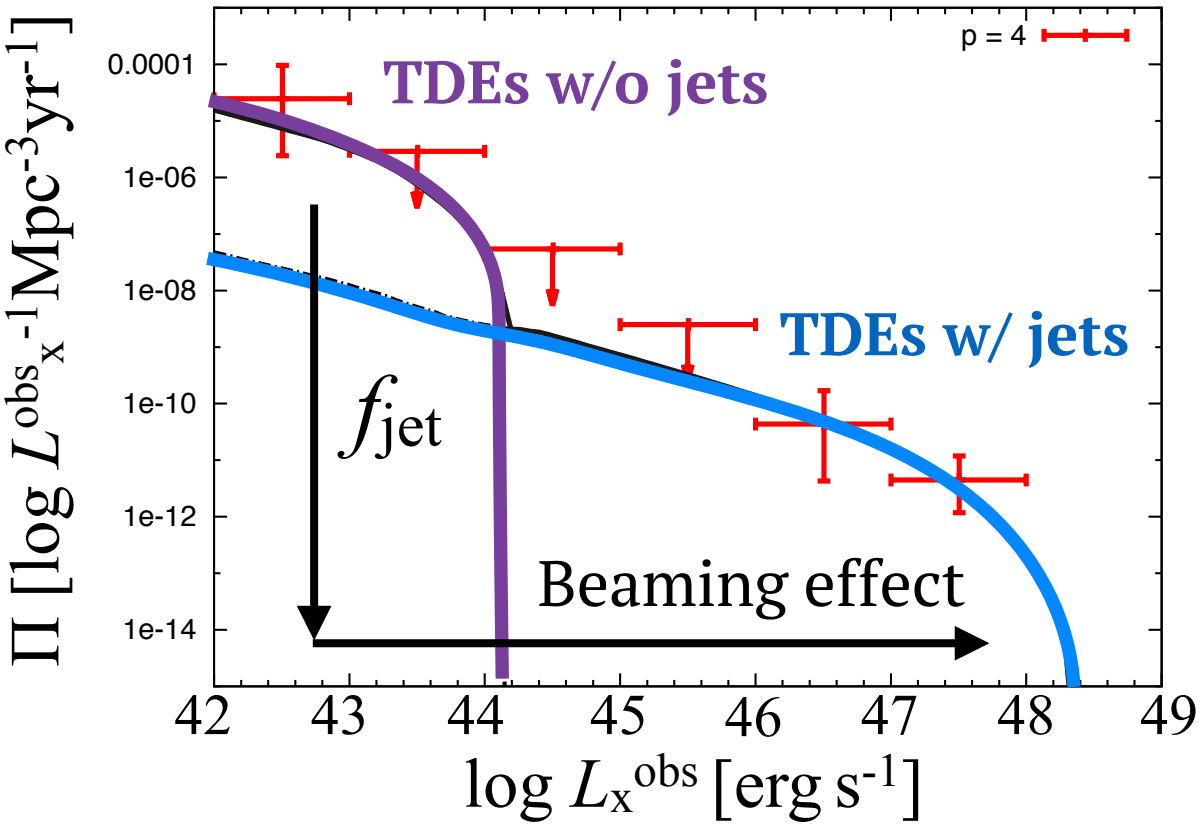
- We considered two LFs of TDEs w/ jets and those w/o jets using the fraction of TDEs w/ jets, $f_{\rm jet}$.
- Only TDE rate ($\psi_0\xi_0$) and the fraction ($f_{\rm jet}$) are free pars.

TDE Hard X-ray LF

- Fitted the data (z, L_x) with the "*Maximum Likelihood*" method.
- Our calc. does not depend on jet detection by considering all possible L_x variation due to presence or absence of the jets and the inc. angles.

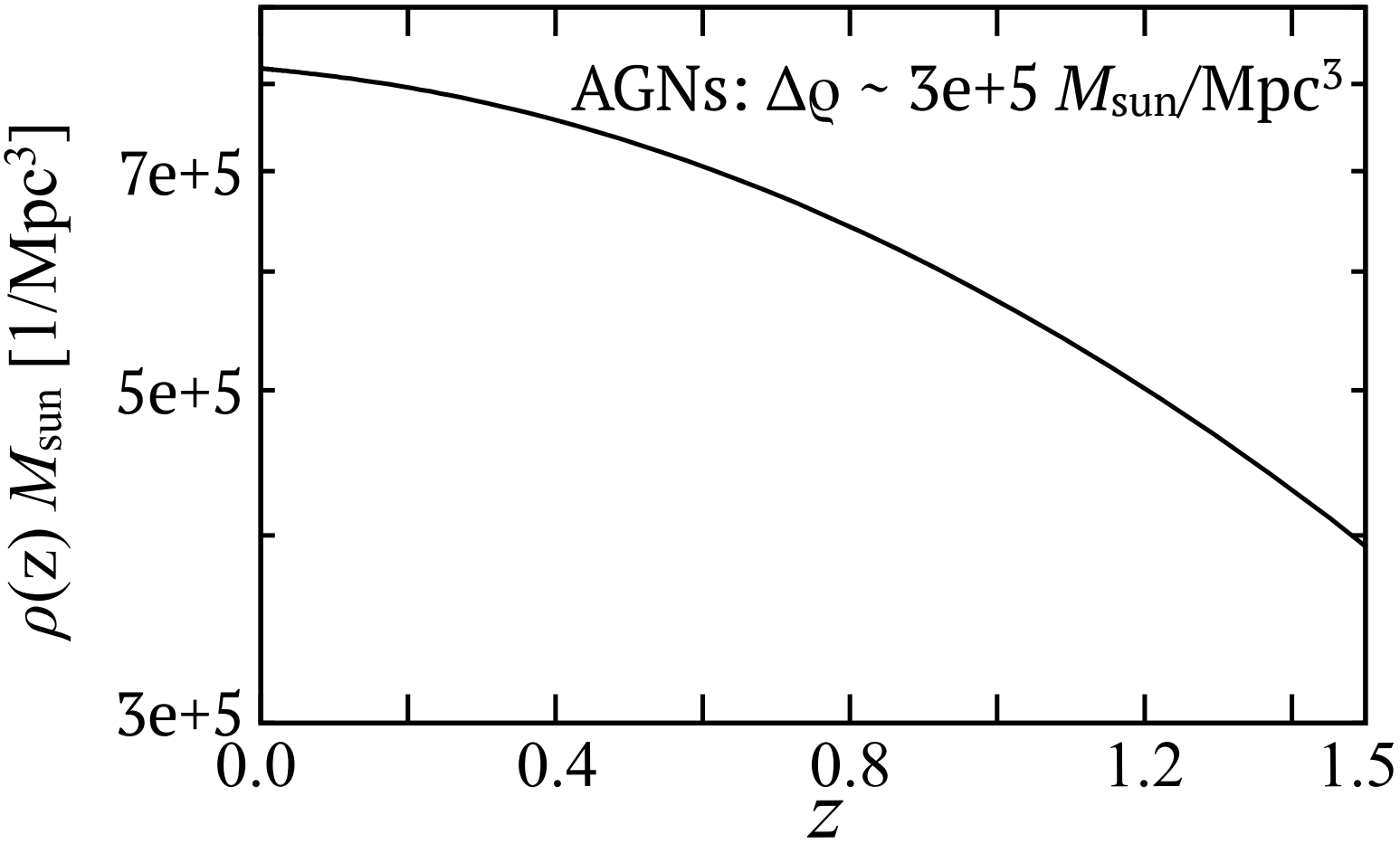


at z = 0.75

- Fraction of TDE w/ jet (f_{jet}) ~ 1%
- TDE rate ($\psi_0\xi_0$) ~ 2×10^{-8} [log $L^{obs}{}_x{}^{-1}$Mpc^{-3}yr^{-1}]

Mass Accretion History

- SMBH mass density calculated by accumulating the accreted mass by AGNs (e.g., Ueda+14).



Mass accreted by TDEs = $\int$ LF (Mpc^{-3} yr^{-1} L^{-1})×Acc. Mass×Time×dL

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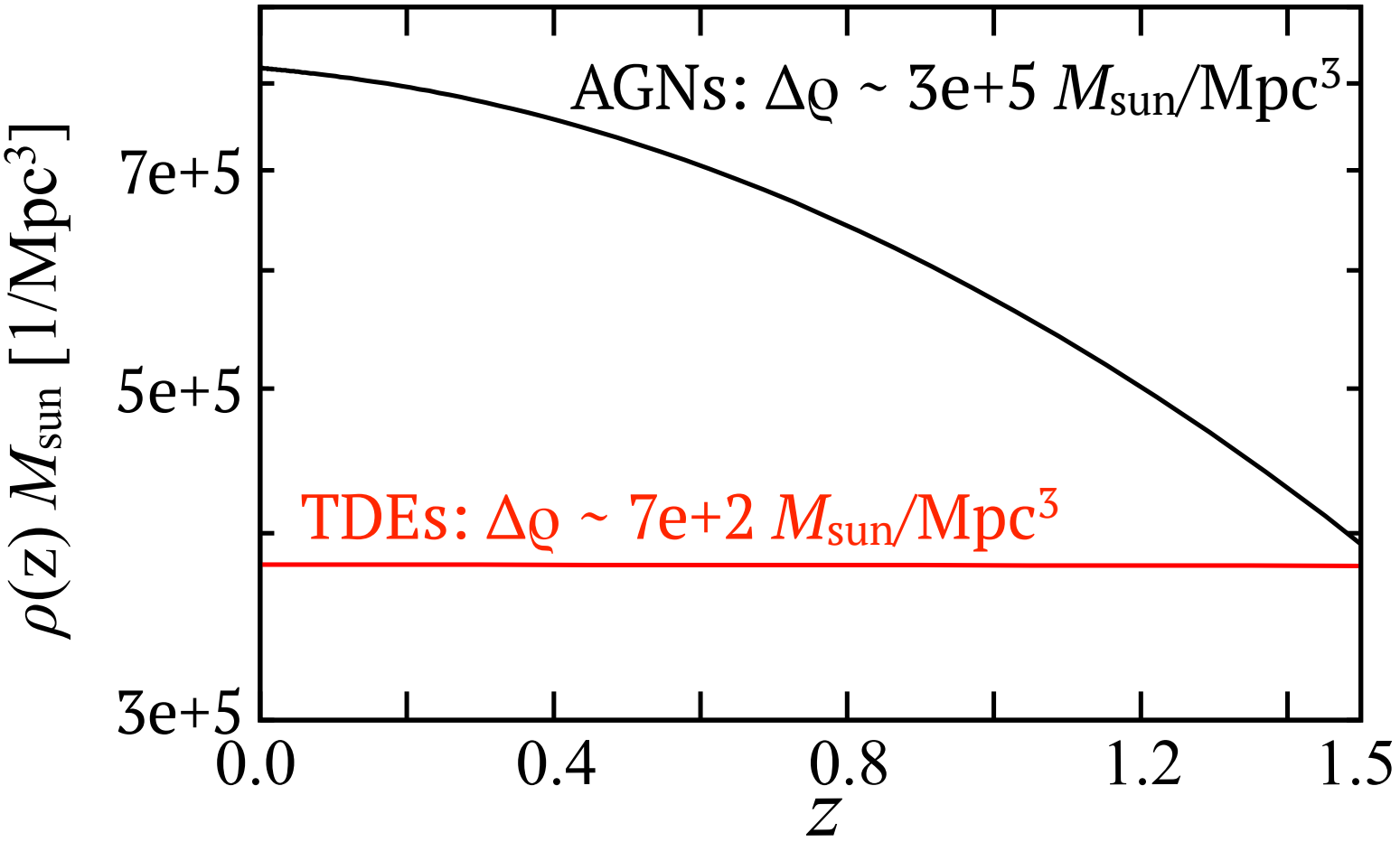

- Contribution of TDEs to the SMBH mass density is much smaller than that of AGN.

Summary

1. All-sky monitor with MAXI has detected 4 TDE candidates in the 37-months since 2009.

2. We derived the hard TDE X-ray luminosity function for the first time.

3. TDEs do not strongly contribute to the total SMBH mass density evolution since $z \sim 1.5$.