Estimation of X-Ray Jet Flux of Black Holes using TCAF

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Jets

- Jets and outflows are important feature of X-ray binaries.
- Jets are observed in both AGN and Galactic black hole candidates (BHC).
- Jets are prominant in Radio.

X-ray Jet
Introduction

- Several BHCs show X-ray jets.
  GRS 1915+105 (Mirabel & Rodriguez, 1994)
  SS433 (Nandi et al. 2005)
  XTE J1550-564 (Tomsick et al. 2003)
  4U 1755-33 (Kaaret et al.2006)
  H 1743-322 (Corbel et al. 2005)

TCAF

- TCAF solution is introduced by Chakrabarti & Titarchuk (1995).
- The solution well explained accretion flow dynamics for several BHCs -
  MAXI J1836-194 (Jana et al, 2016), MAXI J1543-564 (Chatterjee et al., 2016), MAXI J1652-159 (Debnath et al., 2015b), H 1743-322 (Mondal et al., 2014, Bhattacharjee et al., 2017, Chakrabarti et al., 2017), GRS 1915+105 (Debnath et al., 2015a), Swift J1753.5-0127 (Debnath et al., 2017).
- Five input parameters needed : M_{BH}, $\dot{m}_d$, $\dot{m}_h$, X_s, R.

X-ray flux from Jet
Constant Normalization

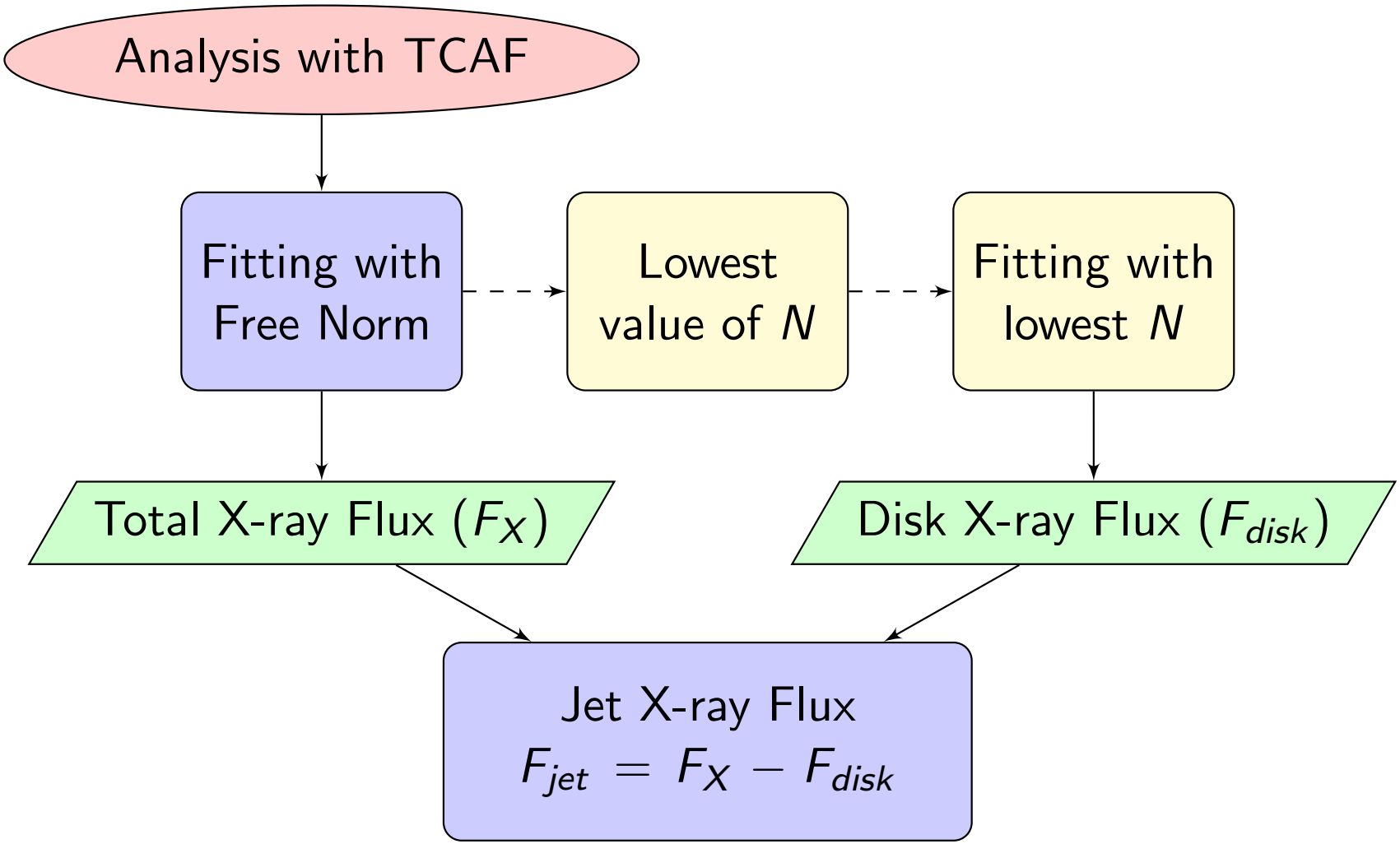
- Normalization is function of distance, mass and inclination angle.
- Constant Normalization is required to fit all the data (Molla et al. 2016, Chatterjee et al. 2016).
- However, if jet is present, higher normalization is needed (Jana et al. 2016).
- Jet also contributes in X-ray, thus higher value is required.

Method of calculating X-ray jets

- Fit was done with free normalization.
- Higher value of normalization is required in some observations.
- We calculated flux $\rightarrow$ this is disk+jet X-ray flux $\rightarrow$ F_X
- We assume jet is absent when lowest value of normalization is required.
- We freeze normalization at lowest value.
- We calculated flux $\rightarrow$ this is disk flux $\rightarrow$ F_{disk}.
- We subtract them to get X-ray flux from jet (F_{jet}).

$$F_{jet} = F_X - F_{disk}$$

Flowchart


Analysis with TCAF
Fitting with Free Norm
Lowest value of N
Fitting with lowest N
Total X-ray Flux (F_X)
Disk X-ray Flux (F_{disk})
Jet X-ray Flux
$F_{jet} = F_X - F_{disk}$

Results
Swift J1753.5-0127

- Active over a decade.
- Spectral Properties $\rightarrow$ Debnath et al. (2017) (communicated)
- Narrow range of normalization required $\sim 1.41 - 1.8$.
- Few observations required higher values $N > 2$
- Lowest value of normalization, $N = 1.41$.

Results
Swift J1753.5-0127

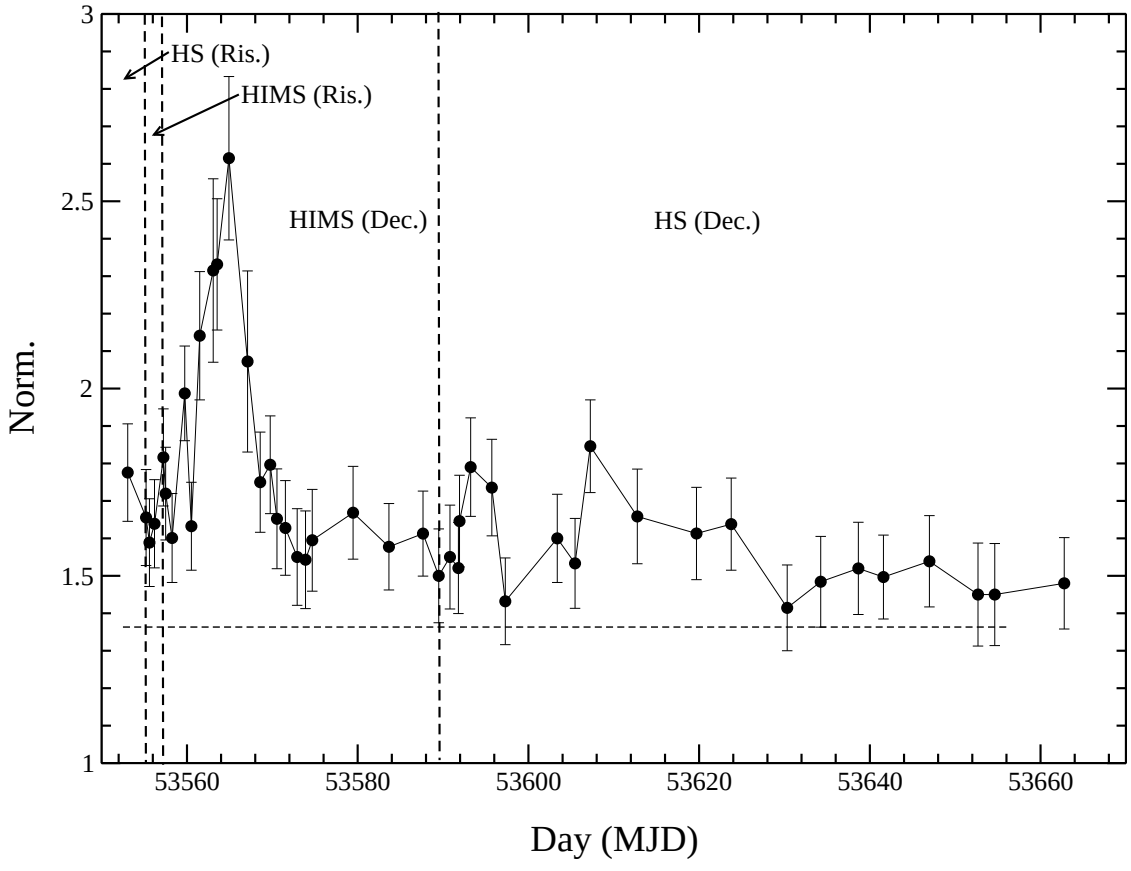


Figure: 1: Variation of TCAF Normalization (N) is shown with day (MJD).

Results
Swift J1753.5-0127

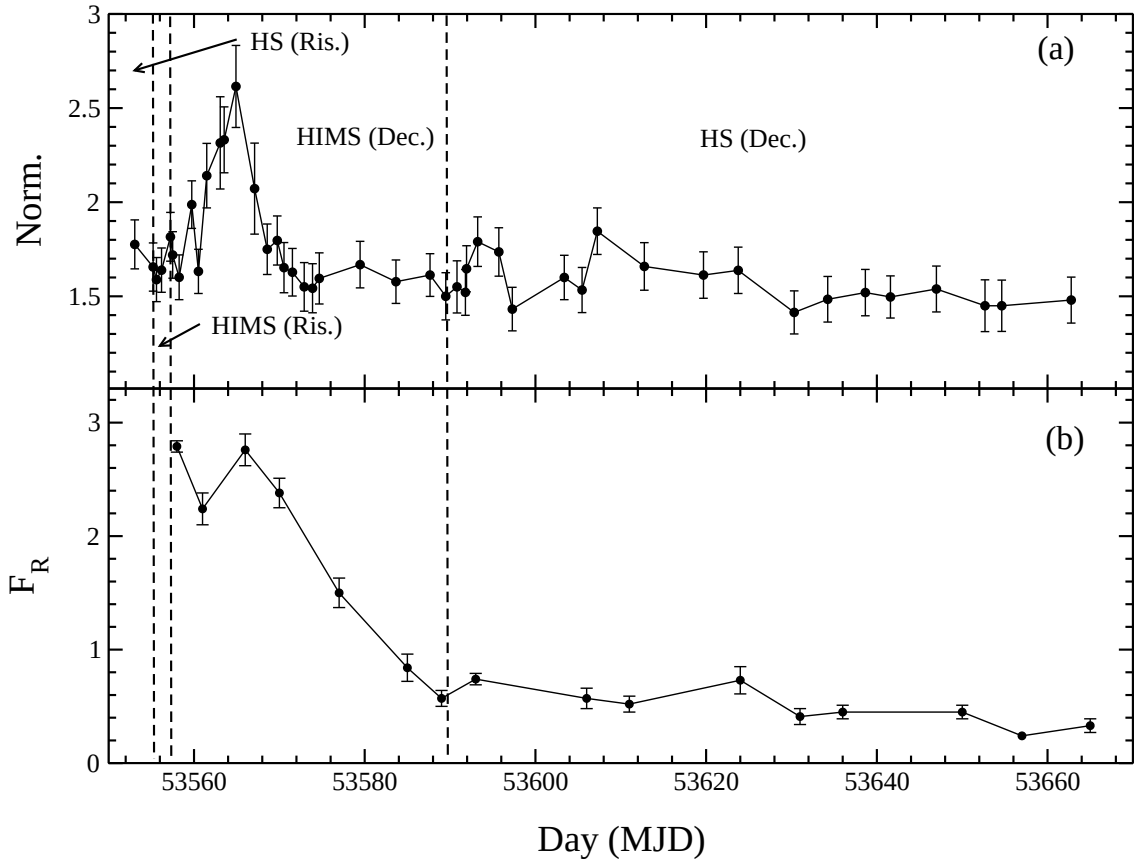


Figure: 2: Variation of (a) TCAF Normalization (N) (b) 4.8 GHz Radio flux (F_R) (Soleri et. al 2005) is shown with day (MJD)

Results

Swift J1753.5-0127

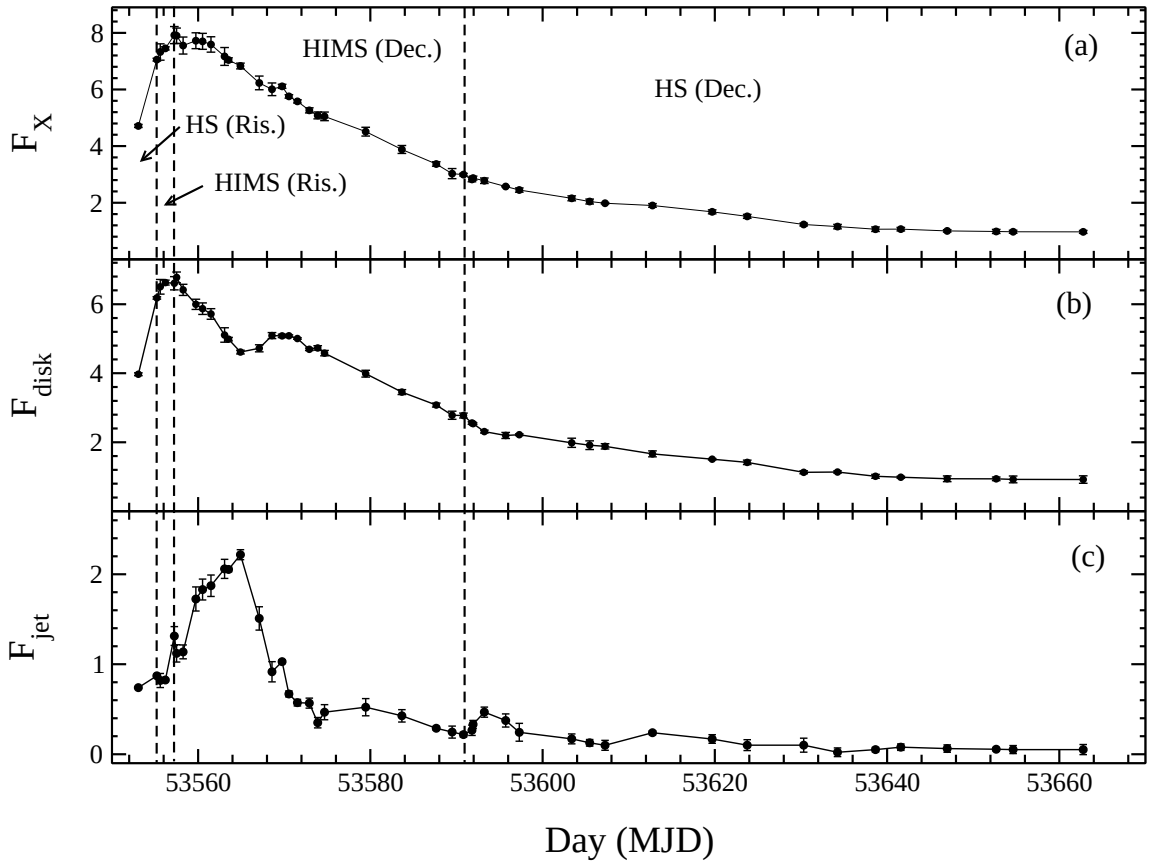


Figure: 3: Variation of (a) total X-ray flux (F_X), (b) disk X-ray flux (F_{disk}), (c) Jet X-ray flux (F_{jet}) is shown with day (MJD)

Results
Swift J1753.5-0127

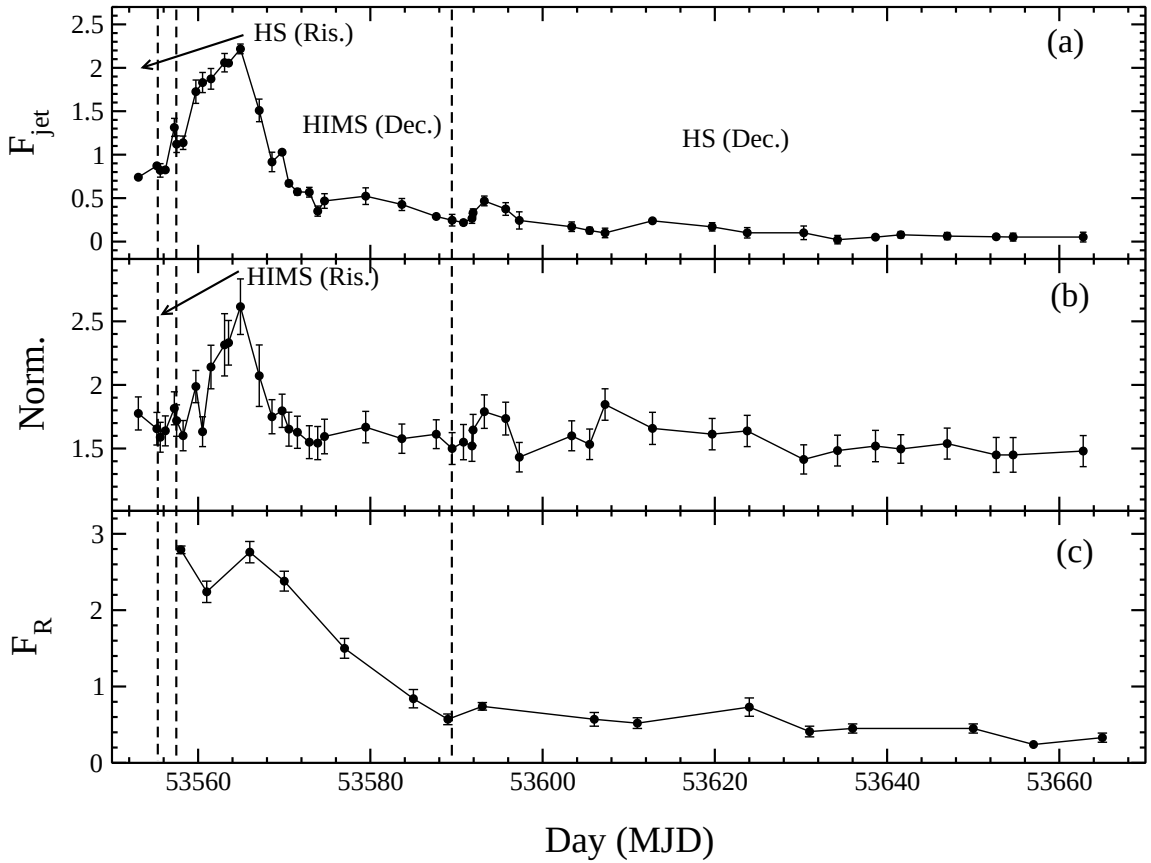


Figure: 4: Variation of (a) Jet X-ray flux (F_{jet}) in $10^{-9} ergs\ cm^2\ s^{-1}$, (b) TCAF Normalization (N), (c) Radio flux (F_R) in mJy(Soleri et. al 2005) is shown with day (MJD) [Jana et al., 2017a]

Results
Swift J1753.5-0127

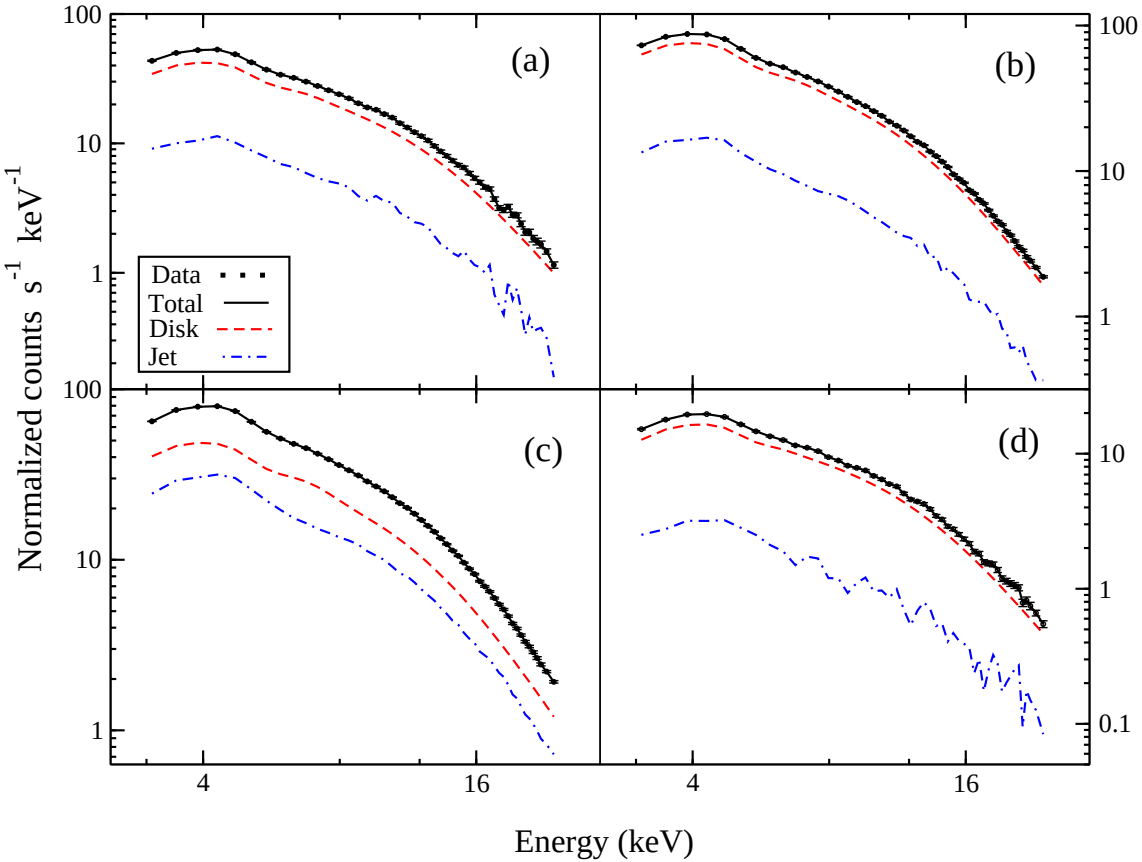


Figure: 5: Jet spectra are shown for (a) HS (Ris.), (b) HIMS (Ris.) (c) HIMS (Dec.) and (d) HS (dec.) [Jana et al., 2017a]

Results
MAXI J1836-194

- Spectral Properties $\rightarrow$ Jana et al. (2016)
- Narrow range of normalization required $\sim 0.25 - 0.35$.
- Few observations required higher values $N > 0.5$
- Lowest value of normalization, $N = 0.25$.

Results
MAXI J1836-194

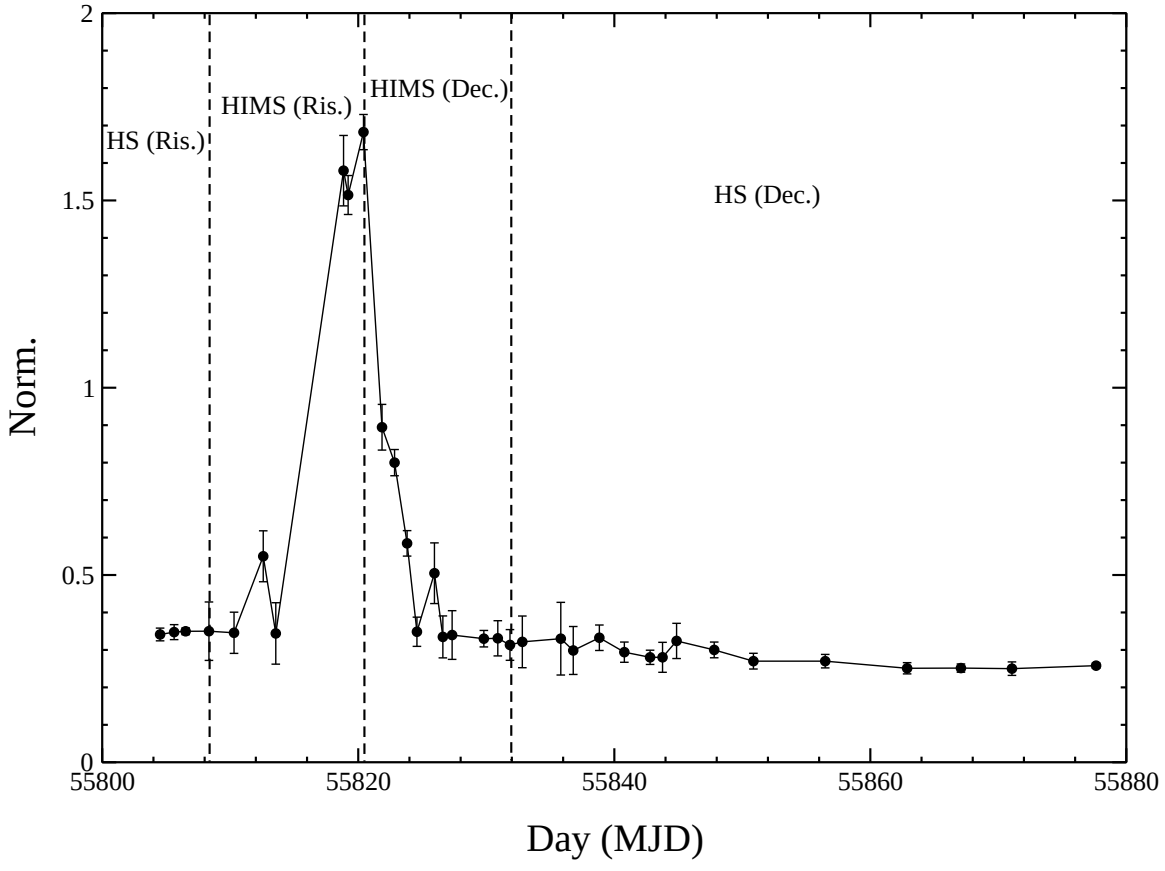


Figure: 6: Variation of TCAF Normalization is shown with day (MJD)

Results
MAXI J1836-194

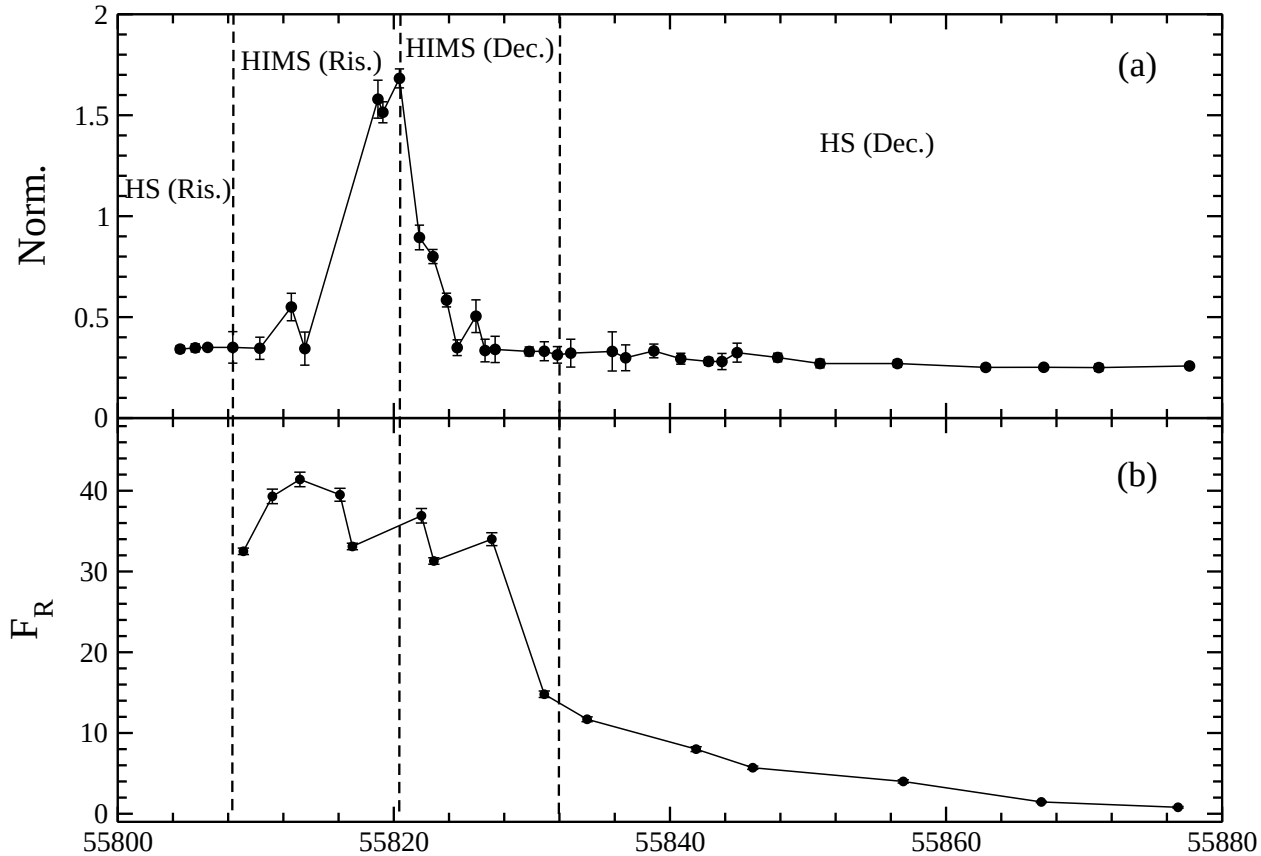


Figure: 7: Variation of (a) TCAF Normalization (N) (b) 7.45 GHz Radio flux (F_R) in mJy (Russel et. al 2015) is shown with day (MJD)

Results
MAXI J1836-194

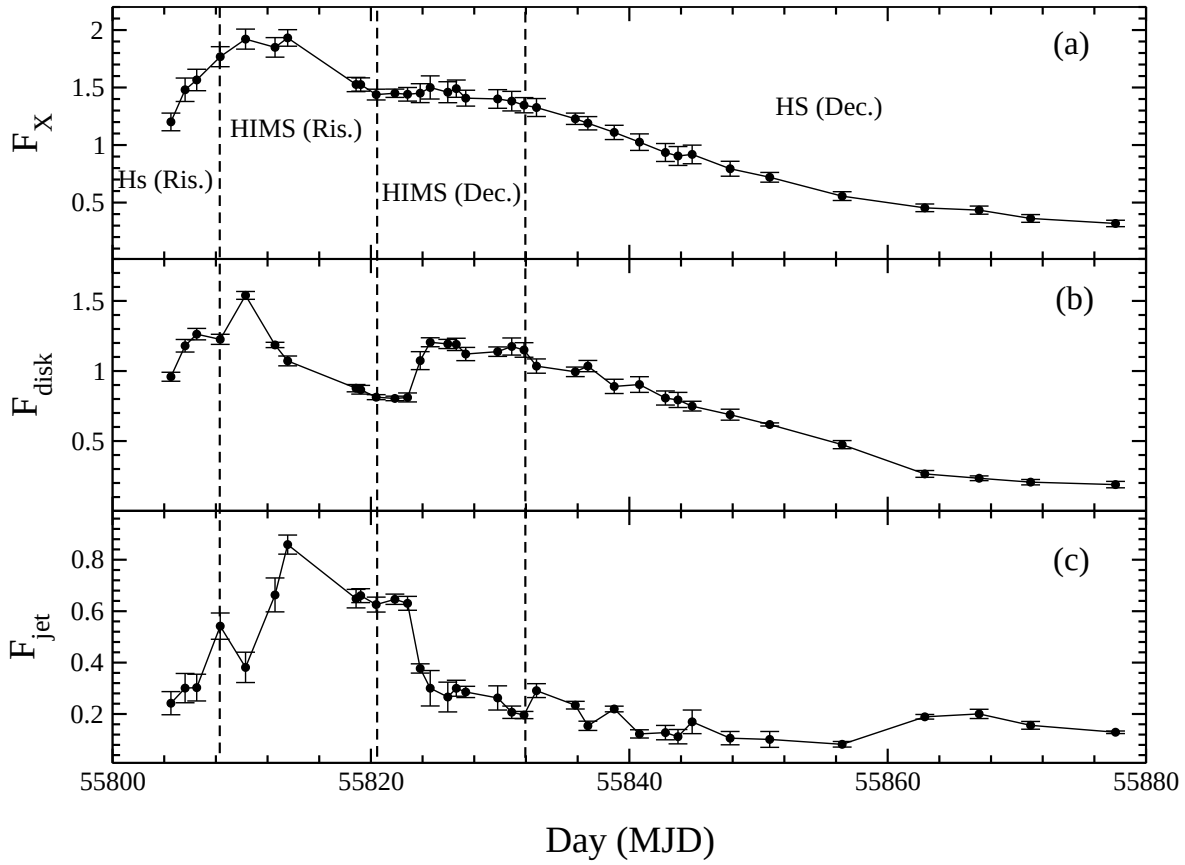


Figure: 8: Variation of (a) total X-ray flux (F_X), (b) disk X-ray flux (F_{disk}), (c) Jet X-ray flux (F_{jet}), is shown with day (MJD). X-ray fluxes are in the unit of $10^{-9} ergs\ cm^2\ s^{-1}$.

Results
MAXI J1836-194

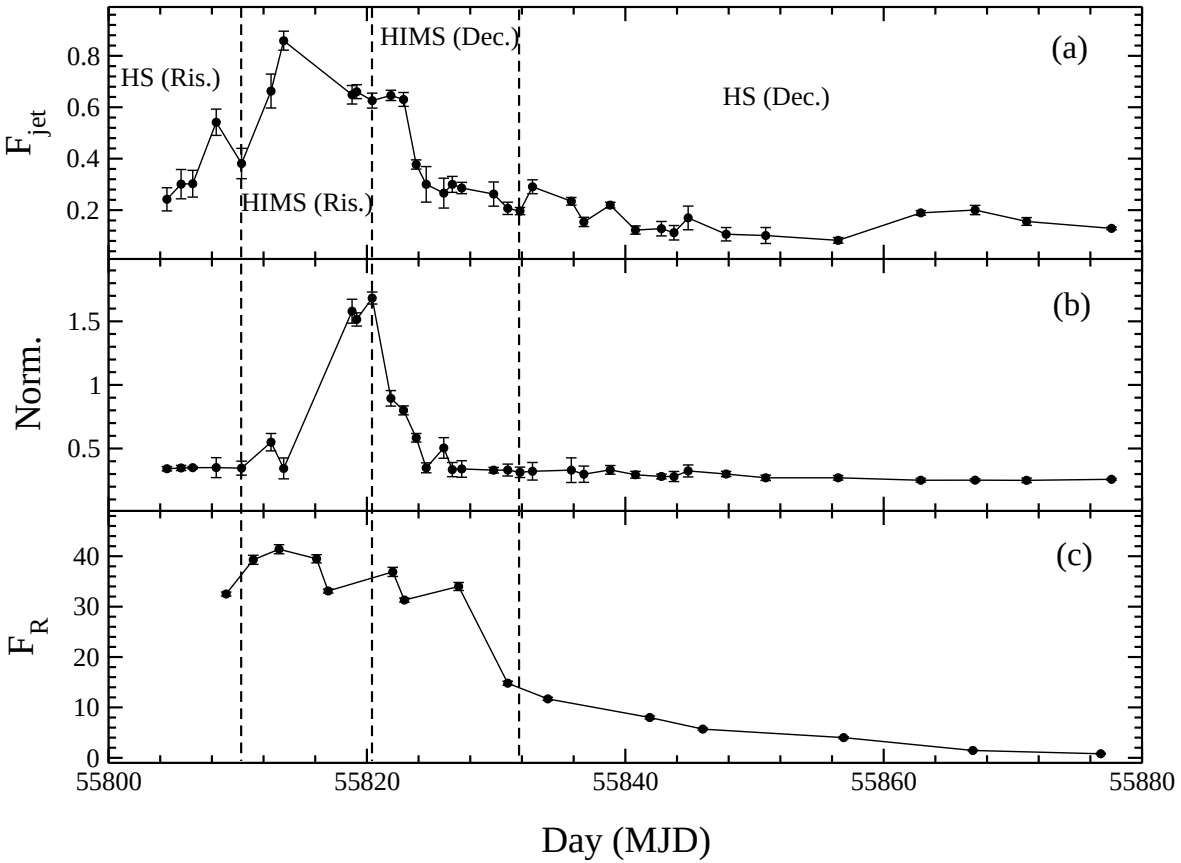


Figure: 9: Variation of (a) Jet X-ray flux ($F)jet$) in $10^{-9} ergs\ cm^2\ s^{-1}$, (b) TCAF Normalization (N), (c) Radio flux (F_R) in mJy is shown with day (MJD) [Jana et al., 2017b]

Results
MAXI J1836-194

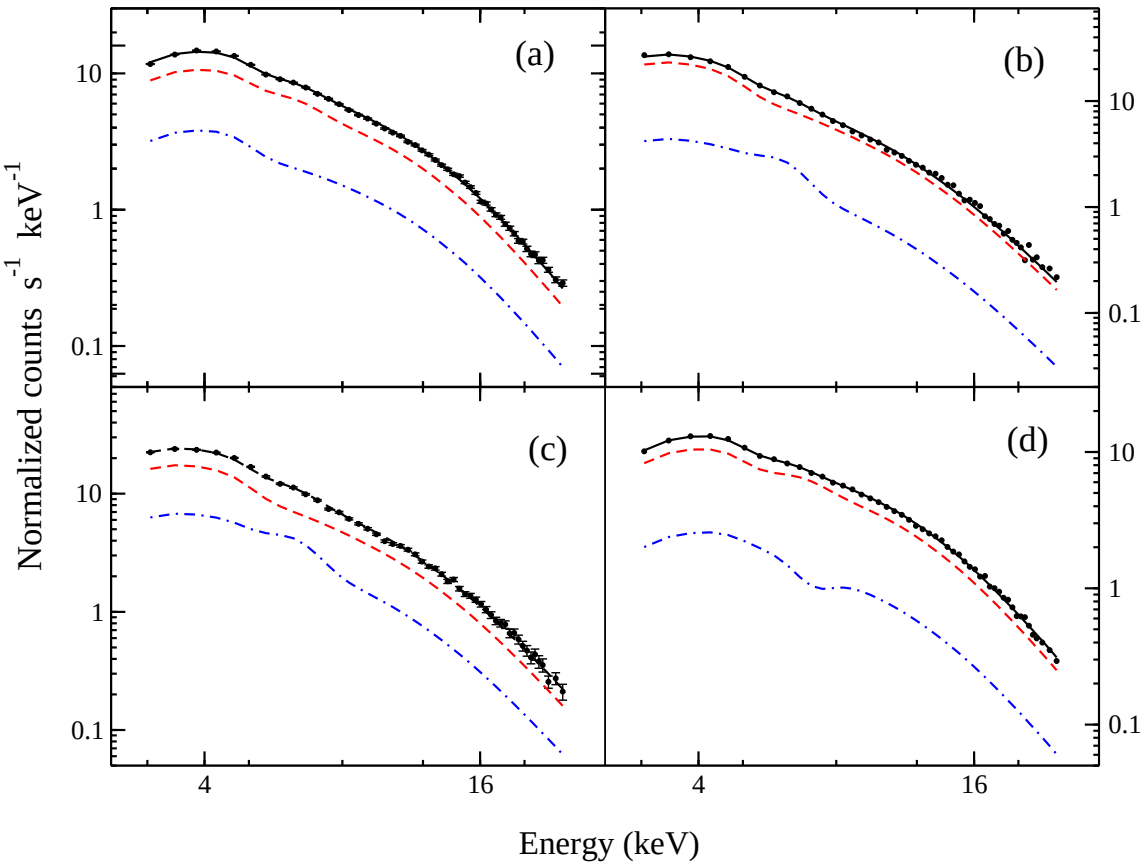


Figure: 10: Jet spectra are shown for (a) HS (Ris.), (b) HIMS (Ris.) (c) HIMS (Dec.) and (d) HS (dec.) [Jana et al., 2017b]

X-ray flux from Jet

Comparison with other Results

- X-ray flux from jets have been calculated.
- X-ray flux from the jet for BHC SS433 is in the order of $10^{-10} ergs\ cm^2\ s^{-1}$ in 3-25 keV energy band (Nandi et al. 2005).
- 4U 1755-33, X-ray flux from jet is observed in the order of $10^{-16} ergs\ cm^2\ s^{-1}$ in quiescent state (Angelini & White, 2003).
- we find for BHC Swift J1753.5-1027, X-ray flux from the jet in the order of $10^{-9} ergs\ cm^2\ s^{-1}$ for 2.5-25 keV energy band.
- Towards the end, the flux is in the order of $10^{-11} ergs\ cm^2\ s^{-1}$.
- It is about 15 % of total X-ray flux.
- For MAXI J1836-194, we have similar observations.

Conclusion

- TCAF can predict if jet is present or not from the normalization.
- TCAF can estimate the X-ray flux which is coming from jets.
- For BHC Swift J1753.5-0127, it is upto 28 % X-ray flux comes from jet.
- In the case of BHC MAXI J1836-194, jet X-ray contribution is upto 44%.

Acknowledgment

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THANK YOU