Constraining Jet Properties in the Black-Hole Transient MAXI J1820+070 through Fast Multi-Wavelength Variability

A. Tetarenko, PC, et al. 2021

Piergiorgio Casella (INAF OA-Roma)

with

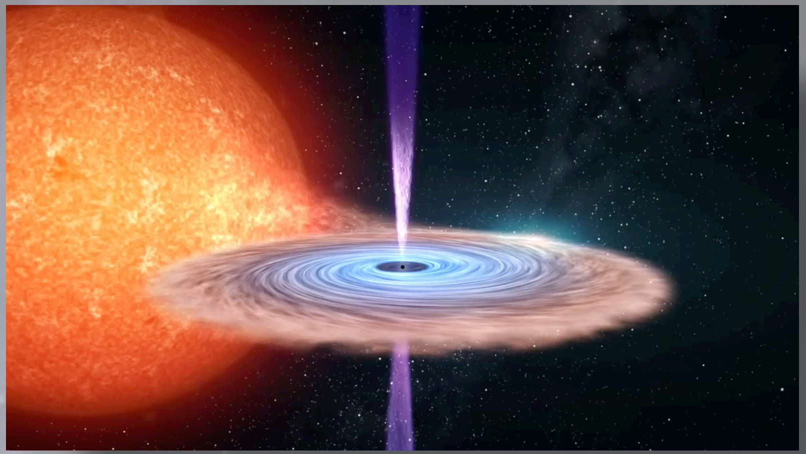
A. Tetarenko (Texax Tech Univ.)

and key help from

J. Miller-Jones (Curtin Univ.), G. Sivakoff (Alberta Univ.),

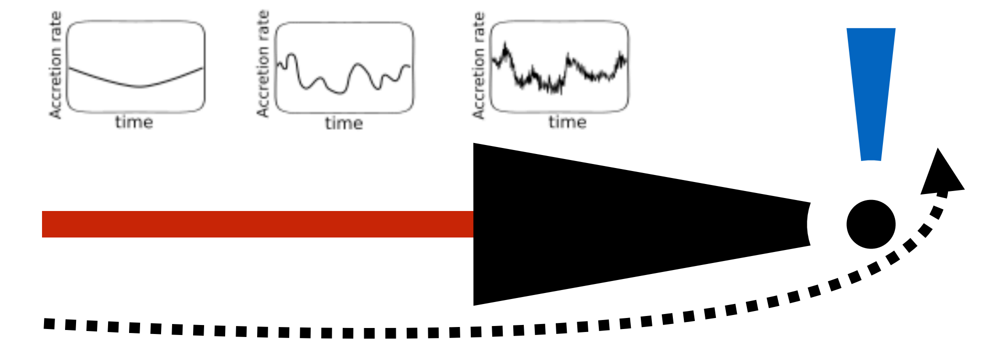
F. Vincentelli (IAC), J. Paice (Southampton Univ.), et al.

- Disk-Jet connection



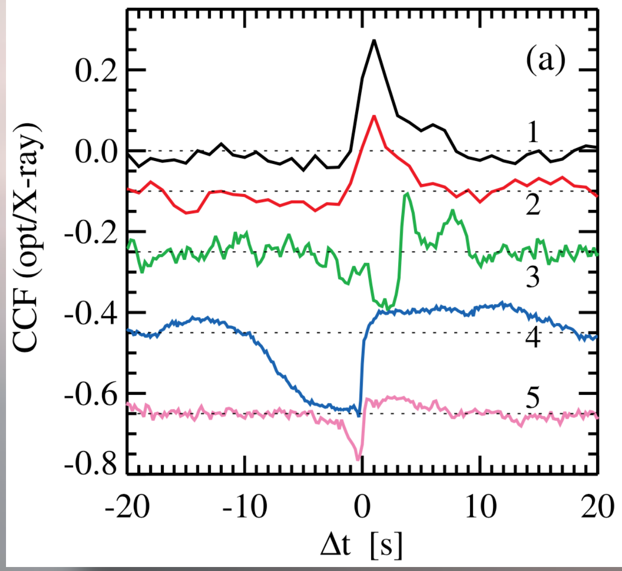
credits: Gandhi, Bachetti

- Tracking propagating fluctuations

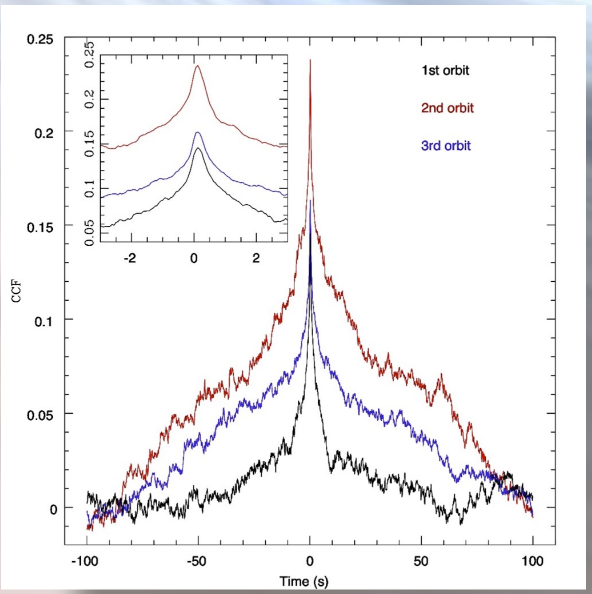


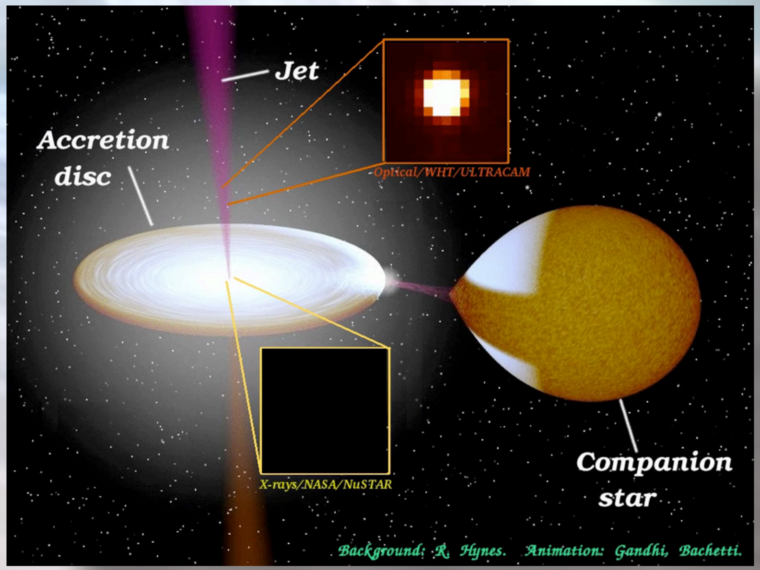
- Fast Multi-λ Variability

Veledina+17



Casella+10

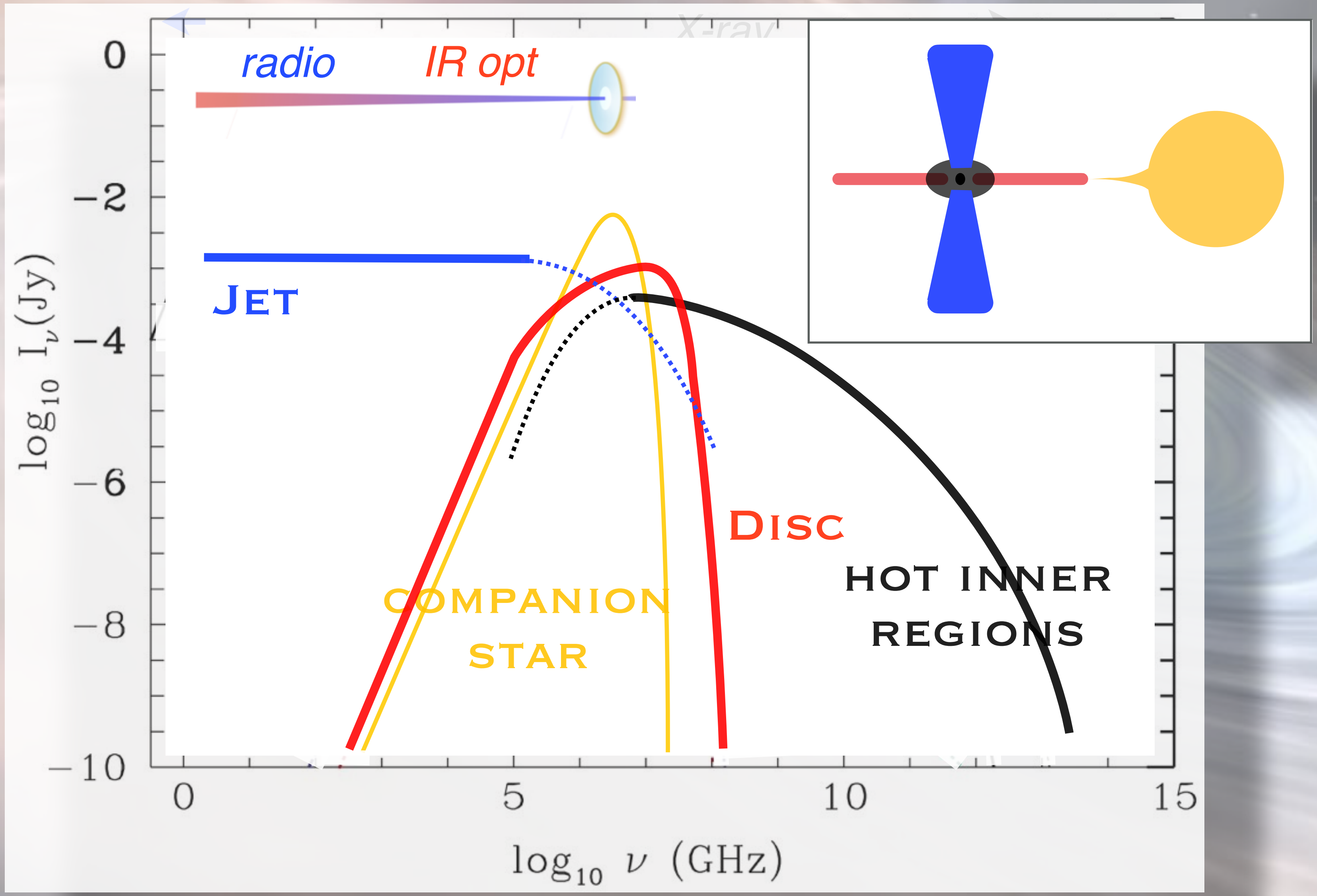




credits: Gandhi, Bachetti

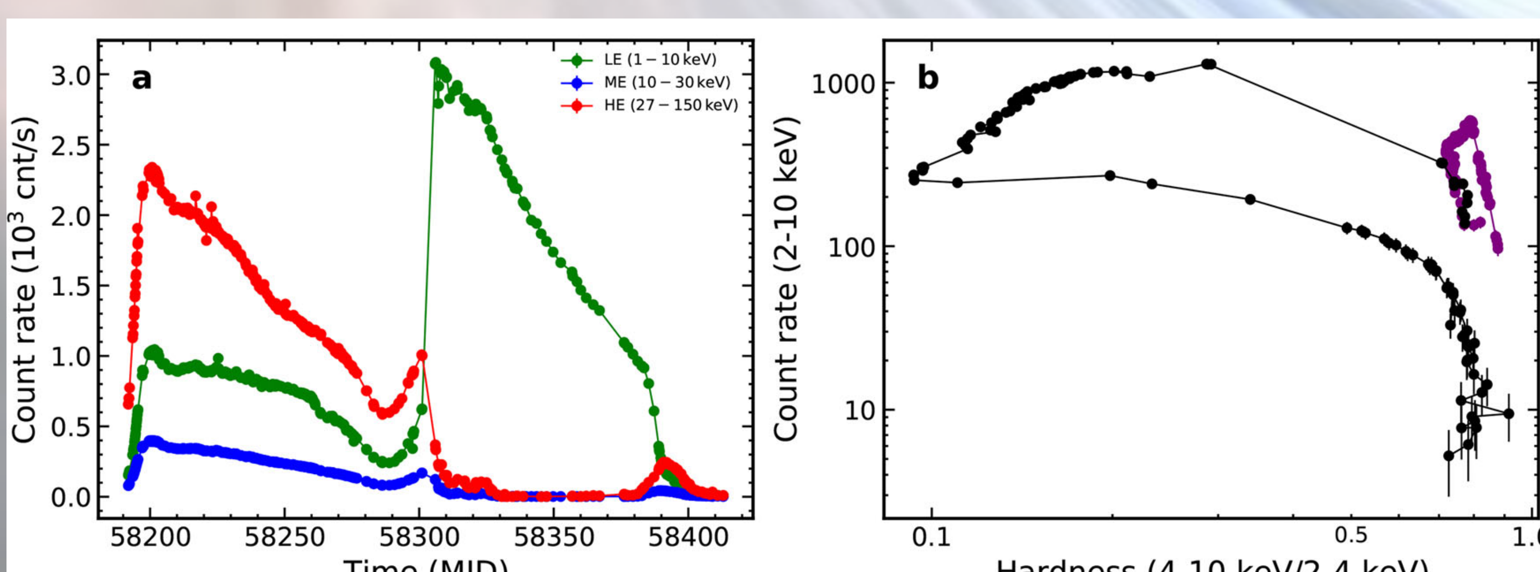
Tracking fluctuations through the JET

We need: + a bright jet + long wavelengths

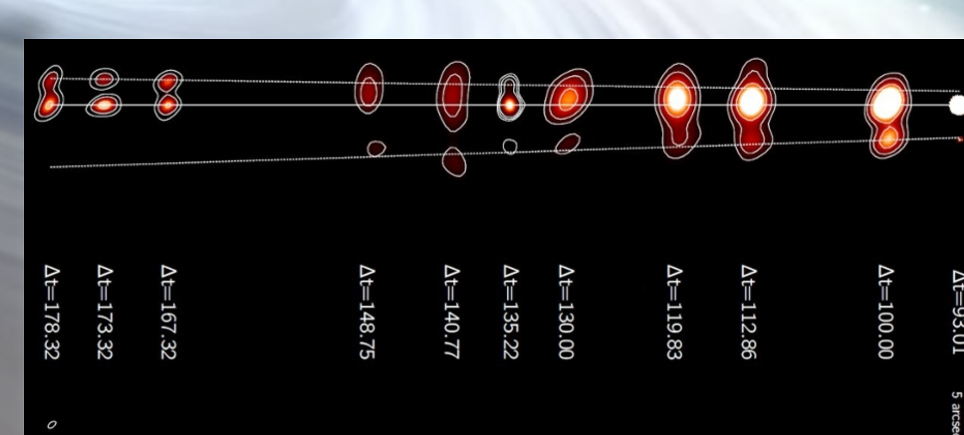


MAXI J1820+70

- One of the brightest BH transients
- Discovery outburst in 2018 - highly variable - bright jet
- Dinamically-confirmed BH (M_{BH} ~ 8.5 M_{sun})
- Radio parallax distance ~ 3 kpc (consistent with Gaia)



B. You+21



J. Bright+21

The ultimate campaign

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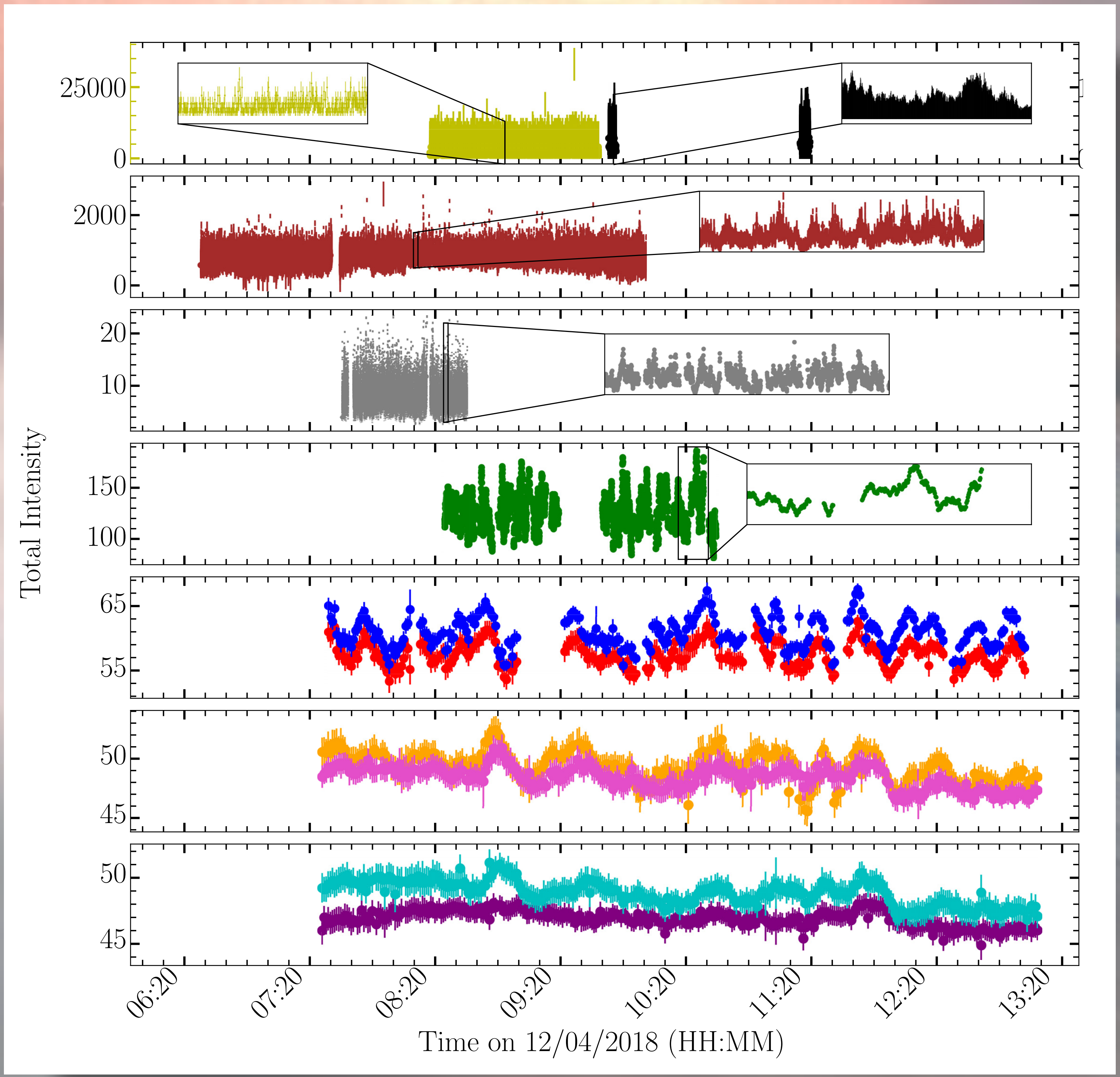

X-rays	XMM - NICER
Optical	ULTRACAM@NTT
Infrared	HAWK-I@VLT
343.5 GHz	ALMA
25.9 / 20.9 GHz	VLA
11 / 8.5 GHz	VLA
7.45 / 5.25 GHz	VLA

All fast timing

Strong jet variability

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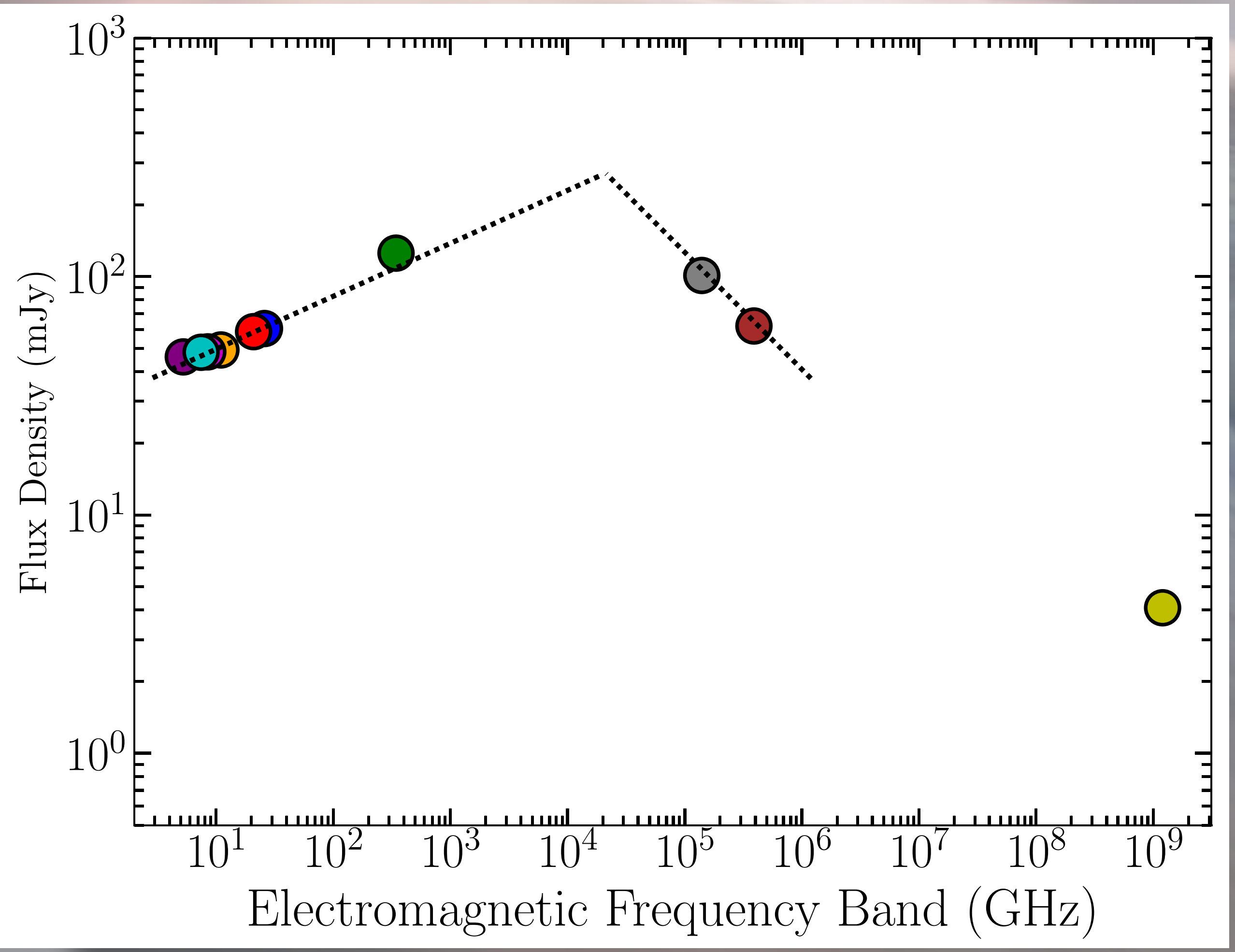
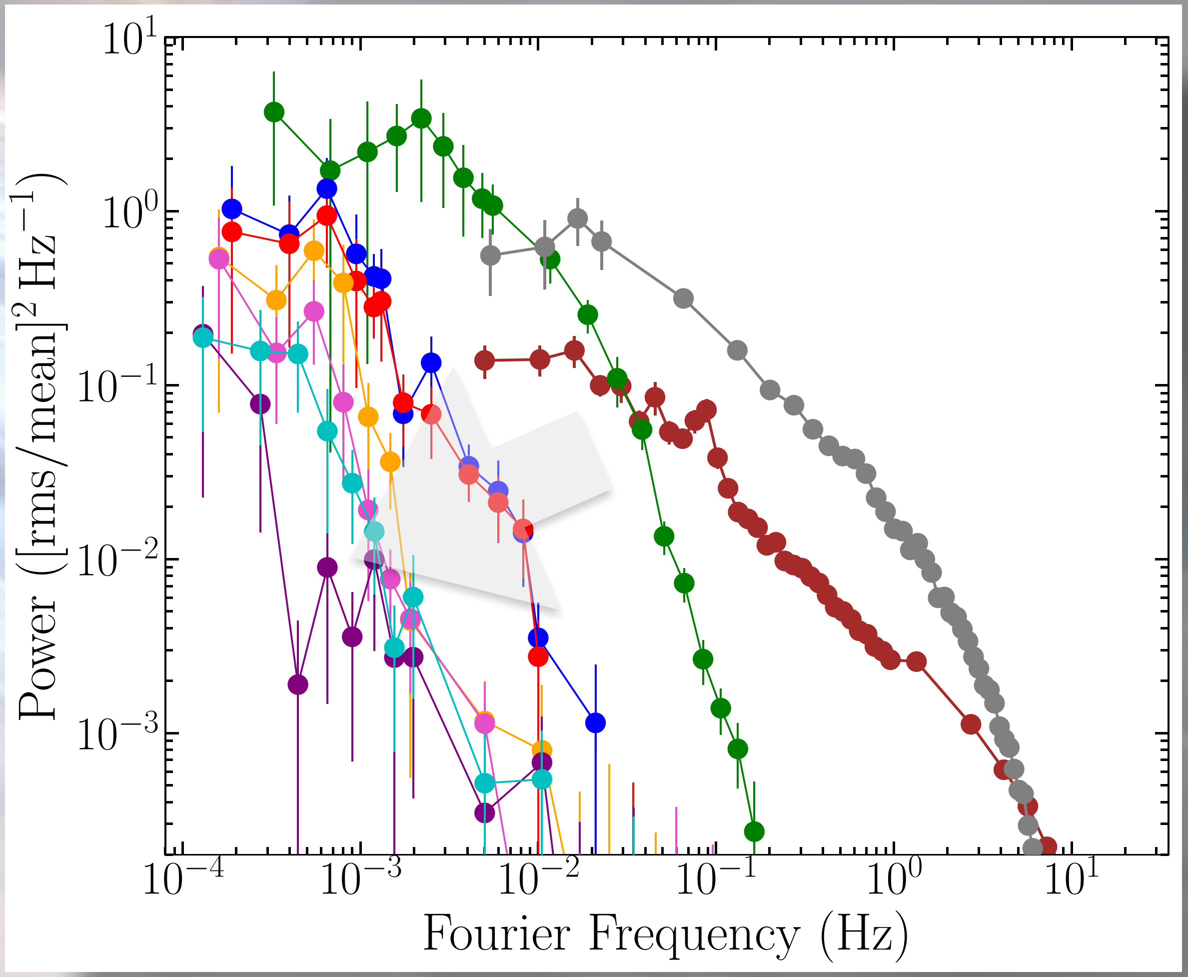
Broad-band SED

bright jet detected



Fourier Power Spectra

highly variable



Strong jet variability

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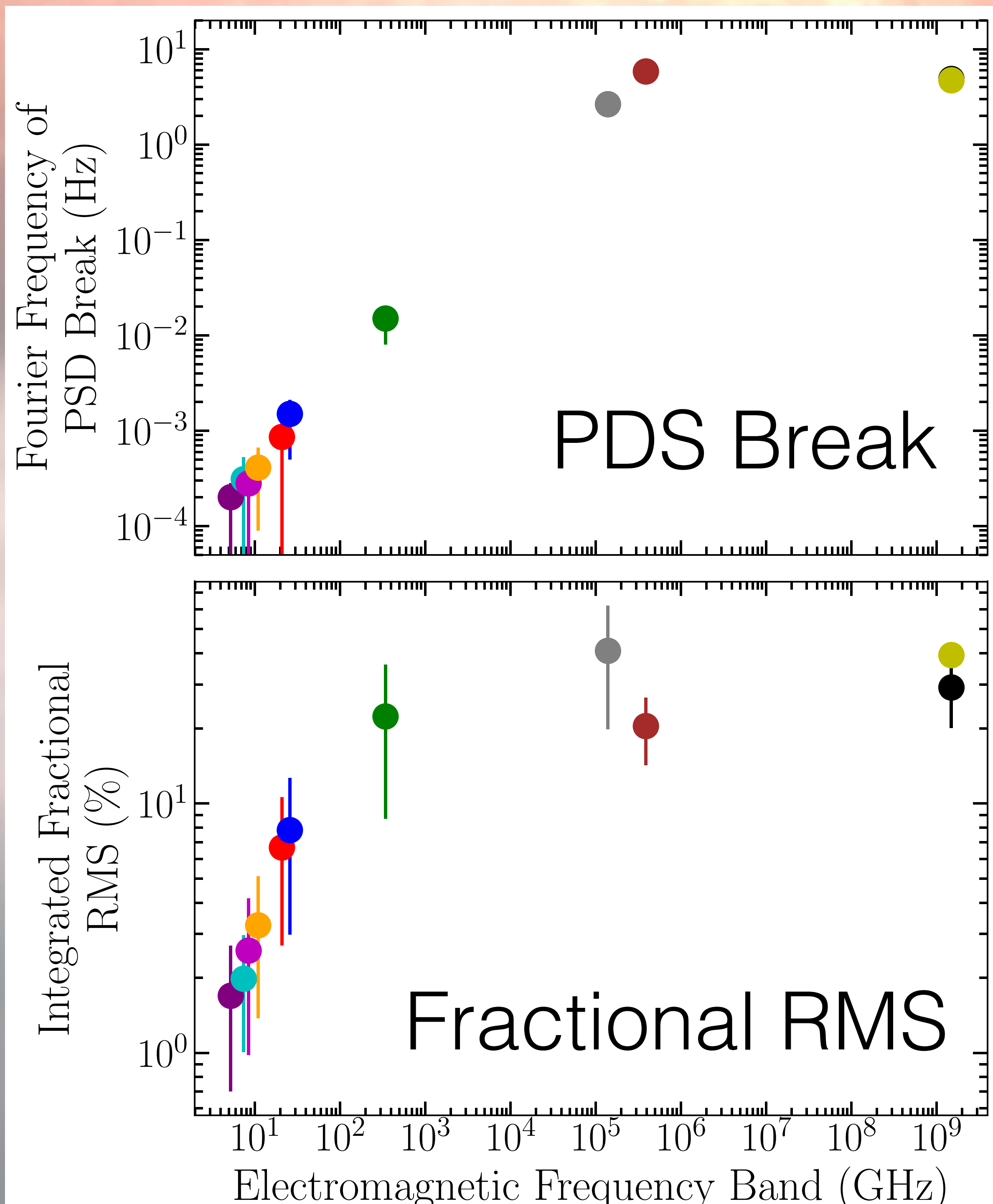
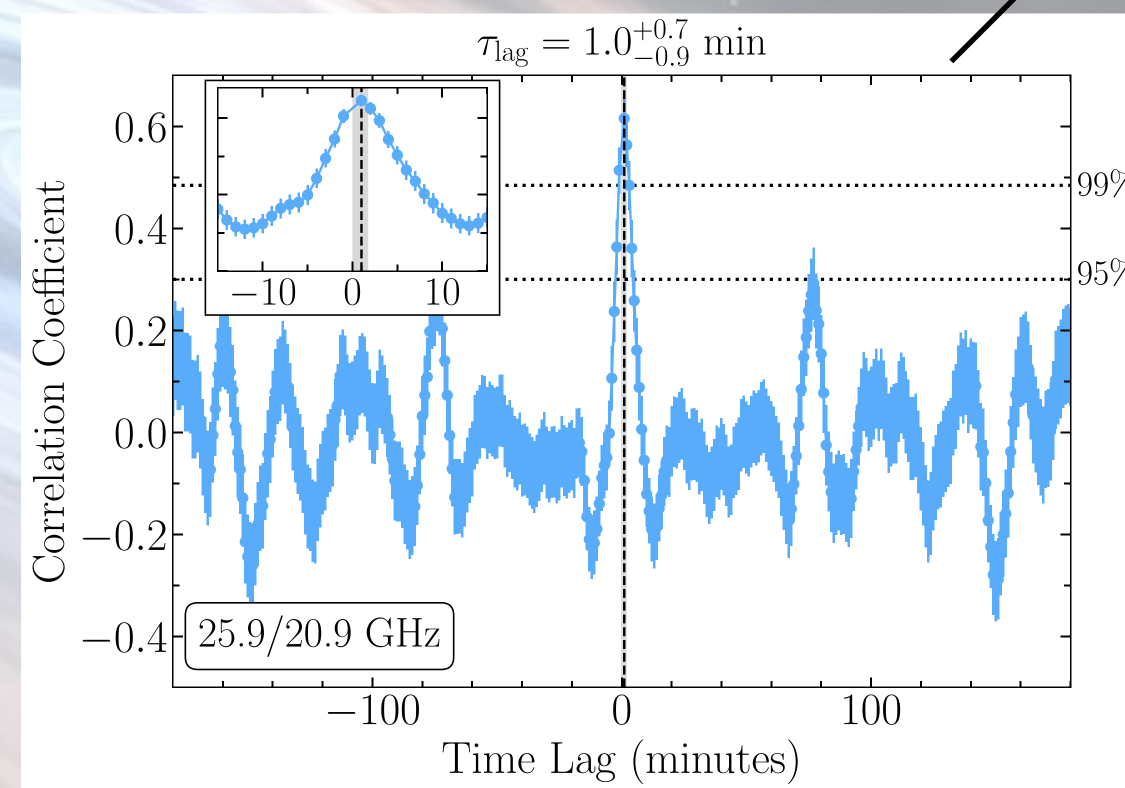


Evolves with λ

Different λ's correlate



Strong jet variability

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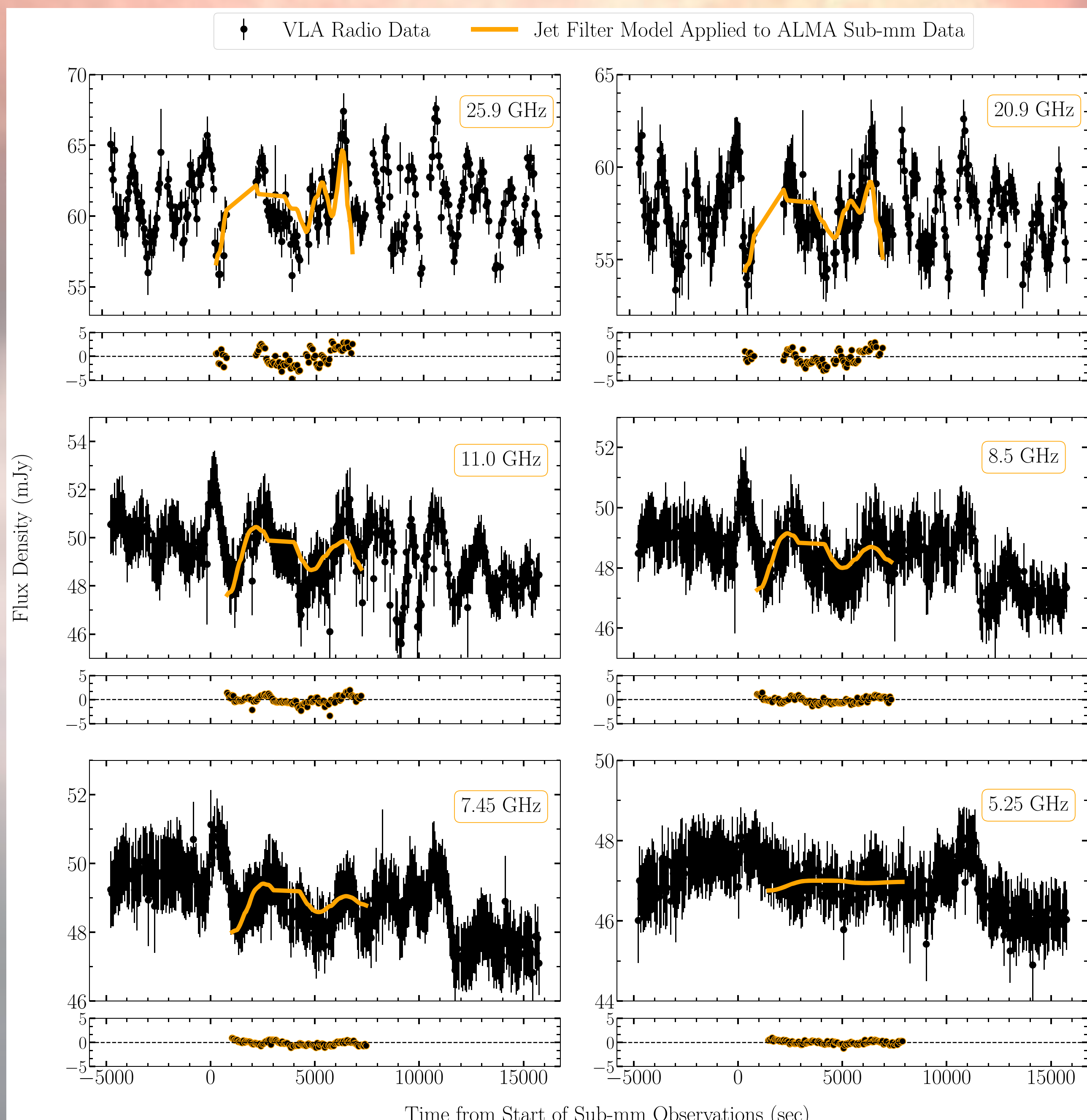

VLA and ALMA too far apart

↓

jet filter to recover correlation

(delay and smooth)

Frequency bands Compared (GHz)	Time lag (min)	σ_{smooth} (s)	z_{smooth} $\times 10^{11}$ (cm)^{a}
343.5/25.9	$4.5^{+0.2}_{-0.4}$	$6.5^{+0.6}_{-0.6}$	$0.5^{+0.1}_{-0.1}$
343.5/20.9	$5.5^{+1.2}_{-1.0}$	$9.2^{+1.6}_{-1.2}$	$0.7^{+0.2}_{-0.2}$
343.5/11.0	$12.6^{+1.2}_{-1.3}$	$13.8^{+2.1}_{-1.6}$	$1.1^{+0.3}_{-0.2}$
343.5/8.5	$15.7^{+1.7}_{-1.8}$	$17.7^{+3.1}_{-2.1}$	$1.4^{+0.4}_{-0.3}$
343.5/7.45	$16.7^{+2.2}_{-1.7}$	$21.8^{+3.8}_{-2.4}$	$1.8^{+0.5}_{-0.4}$
343.5/5.25	$23.6^{+4.5}_{-3.1}$	$37.5^{+8.6}_{-4.2}$	$3.1^{+1.0}_{-0.7}$

Strong jet variability

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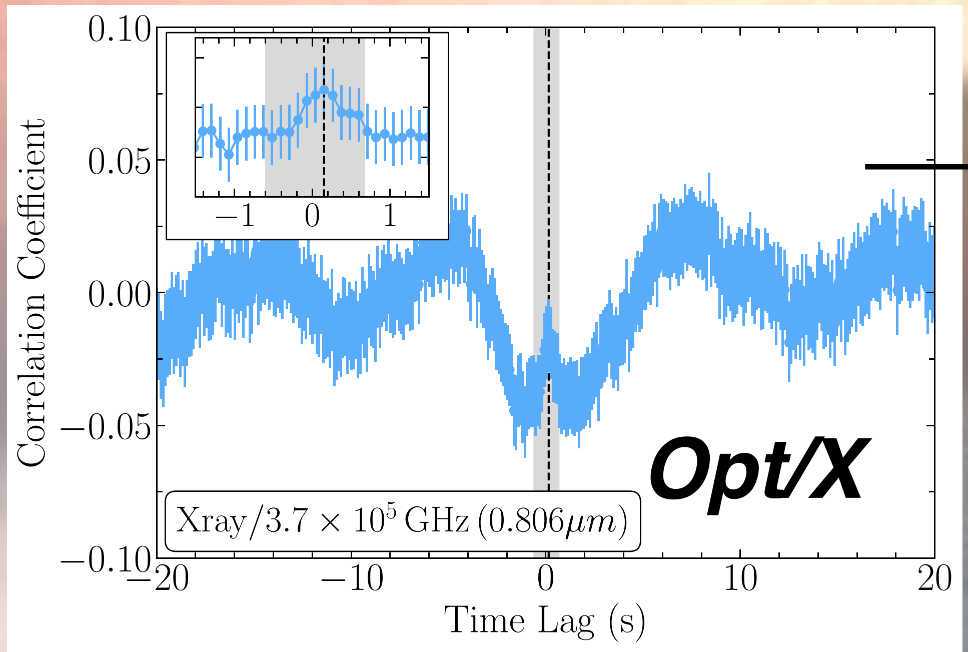
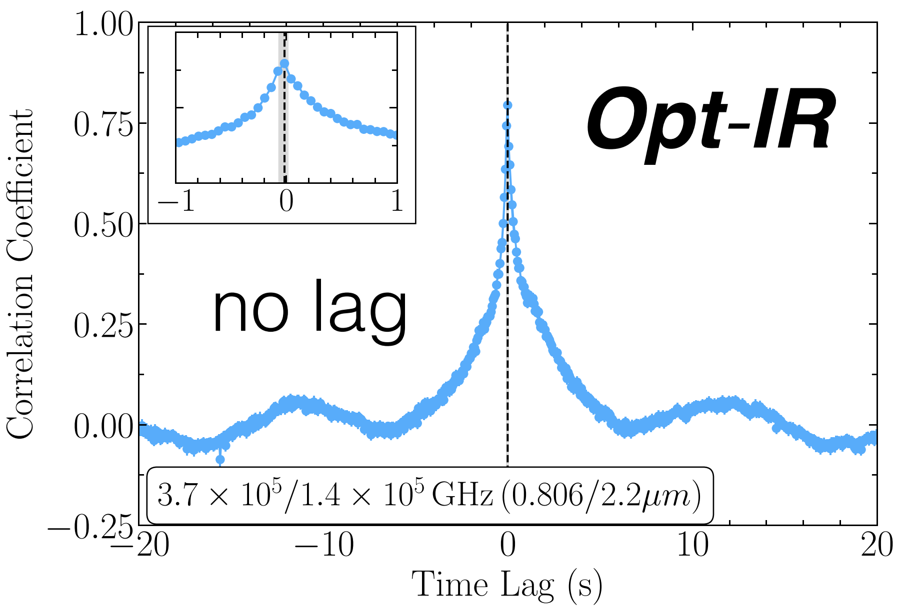
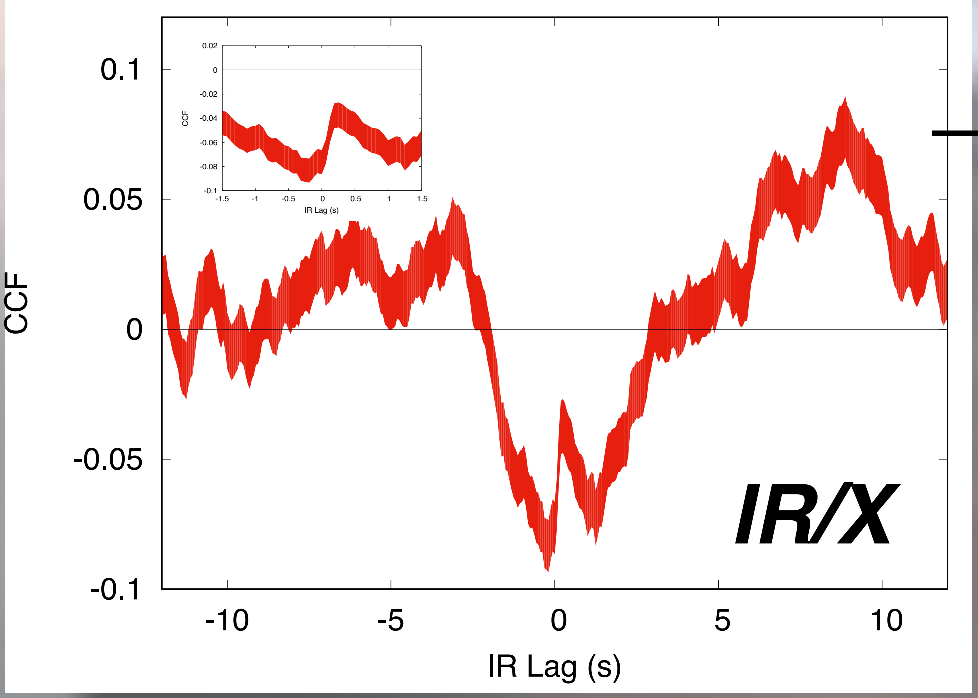
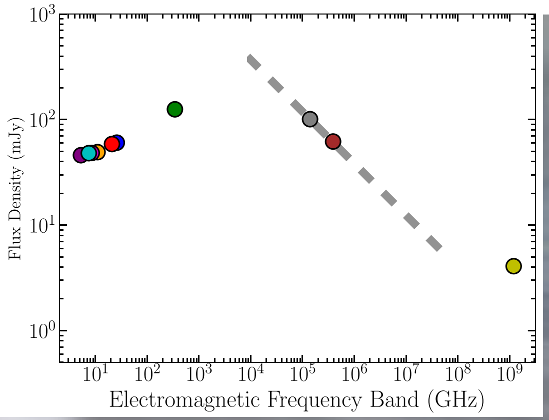


"typical" ~0.1 sec OIR delay







courtesy of Vincentelli F.

optically thin synchrotron cooling

$B > 6 \times 10^3$ G

Modeling

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$$F_\nu = \frac{5.1}{4\pi D^2} z_\nu^{17/8} \sin i^{7/8} \phi^{9/8} C_0 C_1^{-7/8} \delta^{1/4} \boxed{\left(\frac{\nu}{\nu_{\rm ref}}\right)^{\alpha}}$$

(Heinz 06 + non-flat term)

$$C_0 = (2.4\times10^{-17}) \left(\frac{2\xi_B^{3/4} f}{1+\xi_p}\right) \left(\frac{2}{1+\xi_B}\right)^{7/4} \left(\frac{8.4\,\mathrm{GHz}}{\nu}\right)^{1/2} \equiv (8.4)^{1/2} X_0 \nu^{-1/2}\ \mathrm{erg\,s^{-1}\,cm^{-3}\,Hz^{-1}}$$

$$C_1 = (2.3\times10^{-12}) \left(\frac{2\xi_B}{1+\xi_p}\right) \left(\frac{2}{1+\xi_B}\right)^{2} \left(\frac{8.4\,\mathrm{GHz}}{\nu}\right)^{3} f \equiv (8.4)^3 X_1 \nu^{-3}\ \mathrm{cm^{-1}}$$

$$W = 2\left[4p\Gamma^2\beta c\pi(\phi z)^2\right]\ \mathrm{erg\,s^{-1}} \qquad p = \sqrt{\frac{\sin i}{2C_1\delta^2\phi z_\nu}} \left(\frac{z}{z_\nu}\right)^{-2} \qquad z_\nu = \left(\frac{W}{8\Gamma^2\beta c\pi\phi^{3/2}}\right)^{2/3} \left(\frac{2X_1(8.4)^3\delta^2}{\sin i}\right)^{1/3} \nu^{-1}\ \mathrm{cm}$$

$$\boxed{f_{\rm break} = \frac{\beta c\delta}{z_\nu}} \qquad \tau_{\rm lag} = z_{\rm norm}\left(\frac{1}{\nu_{\rm low}} - \frac{1}{\nu_{\rm high}}\right)\frac{(1-\beta\cos i)}{\beta c}\ \mathrm{s}$$

simplified assumption

Modeling (key points)

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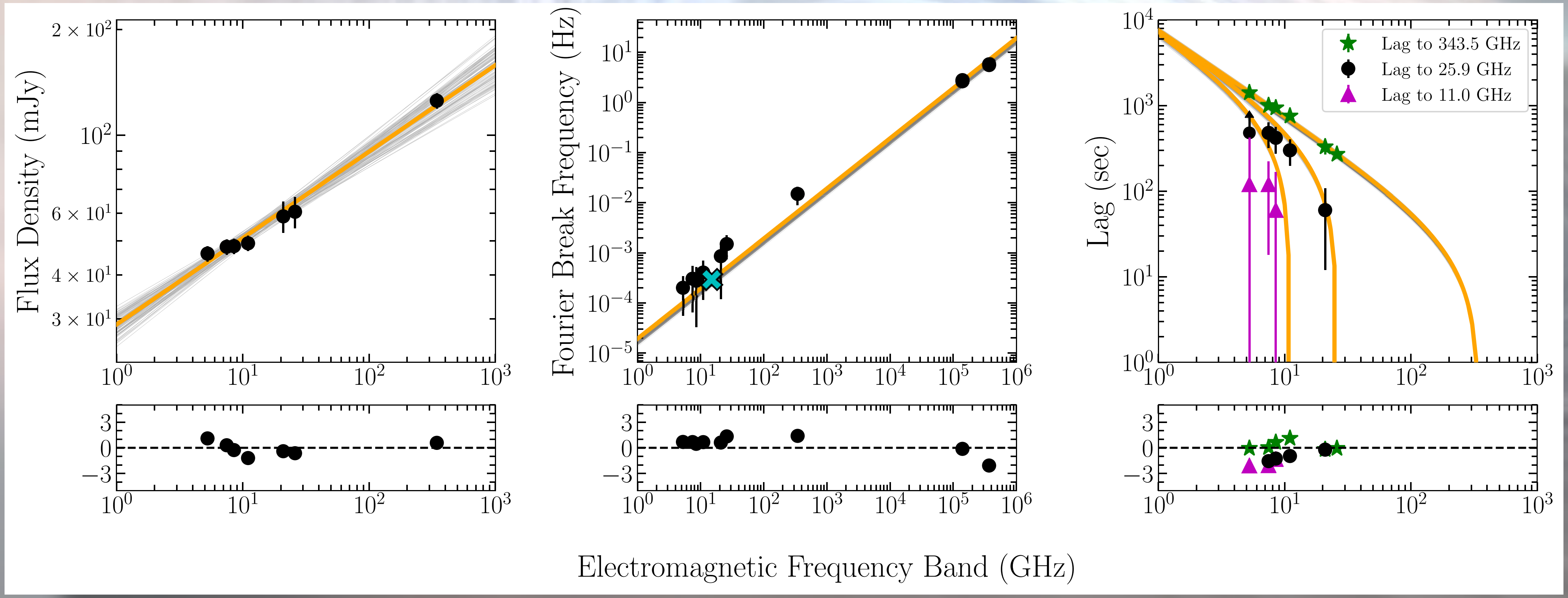
- + Blandford & Konigl 79 (Heinz 06)
- + Additional term accounting for non flat spectrum
- + PDS break scales with jet length at given λ
- + Solve for jet power, opening angle, speed



Results & Conclusions

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- Jet scale consistent with estimates for transient jet
- $\Gamma \sim 7$ (+/-1) fastest compact jet so far *(but brightest)*
- $P_{jet} \sim 6\ 10^{37}$ erg/s ~60% $L_{1\text{-}100keV}$ *(possible feedback?)*
- Leptonic jet, otherwise $P_{jet} >> L_{1\text{-}100keV}$ *(but Carotenuto?)*
- Opening angle $\alpha \sim 0.45°$ *(among narrowest)*
- $F_{receding\ jet} \sim 0.2\ F_{approaching\ jet}$ *(plans to look for it)*

Spectral and timing together - Self consistent picture

Variability: key physical ingredient - useful tool

The technique is clearly powerful -> more models

(…but campaigns are **very** hard to build…)