NGC 4593 MONITORING PROGRAM: HST RESULTS

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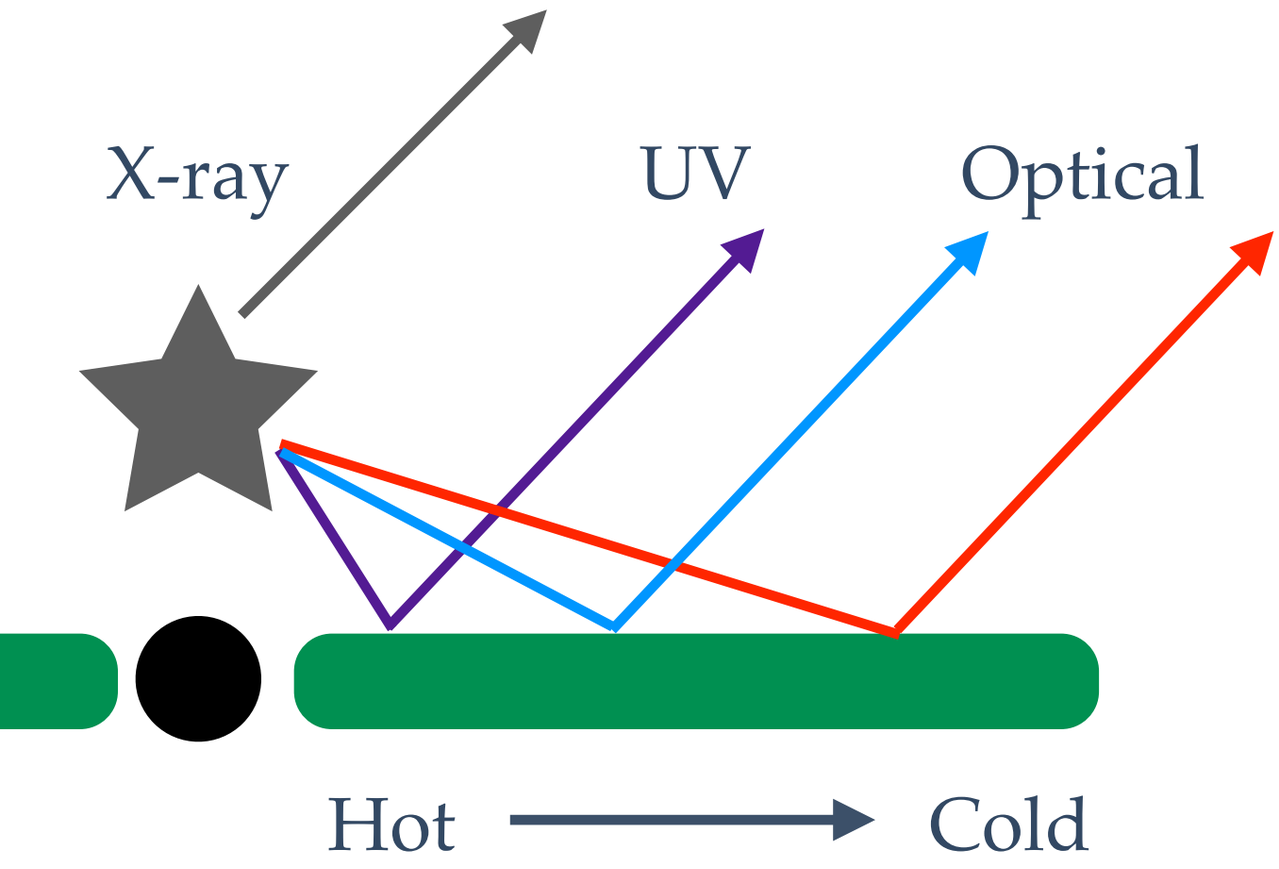
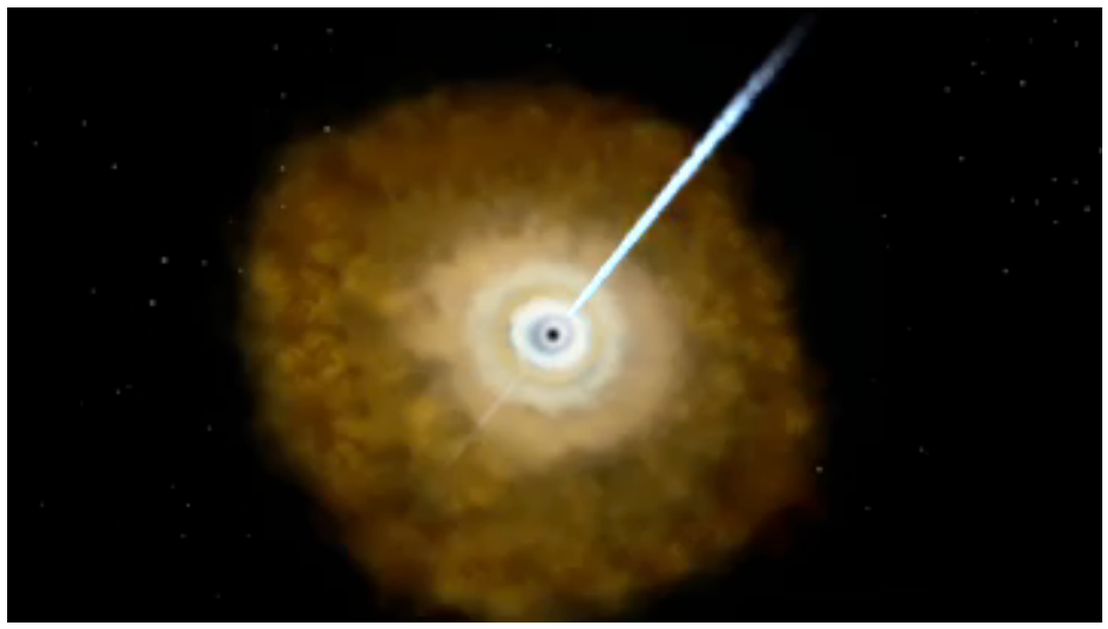
THERMAL REPROCESSING

- Hot, inner disk sees variable irradiating source before cooler, outer disk
- Expect correlated continuum bands, with lags that depend on the temperature profile of the disk





TEMPERATURE PROFILE

$$T(R) = \left(\frac{3GM\dot{M}}{8\pi\sigma R^3} + \frac{(1-A)L_X H}{4\pi\sigma R^3} \right)^{1/4}$$

Viscous Irradiation

$$T = X\frac{hc}{k\lambda}$$

where X ~ 3 for blackbody radiation
assuming a flux-weighted emission radius

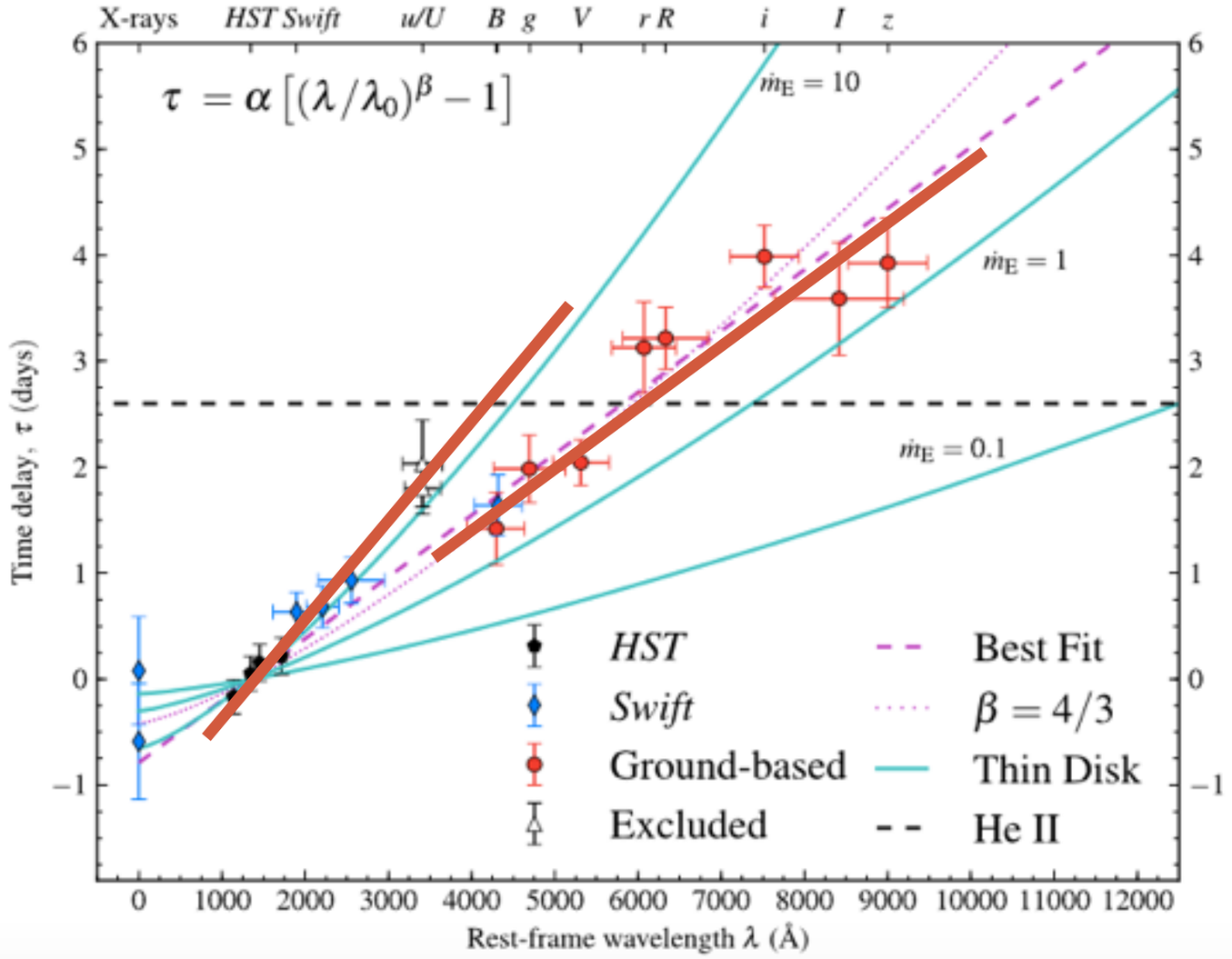
$$R \propto (M\dot{M})^{1/3} T^{-4/3} \longrightarrow \tau \propto (M\dot{M})^{1/3} \lambda^{4/3}$$

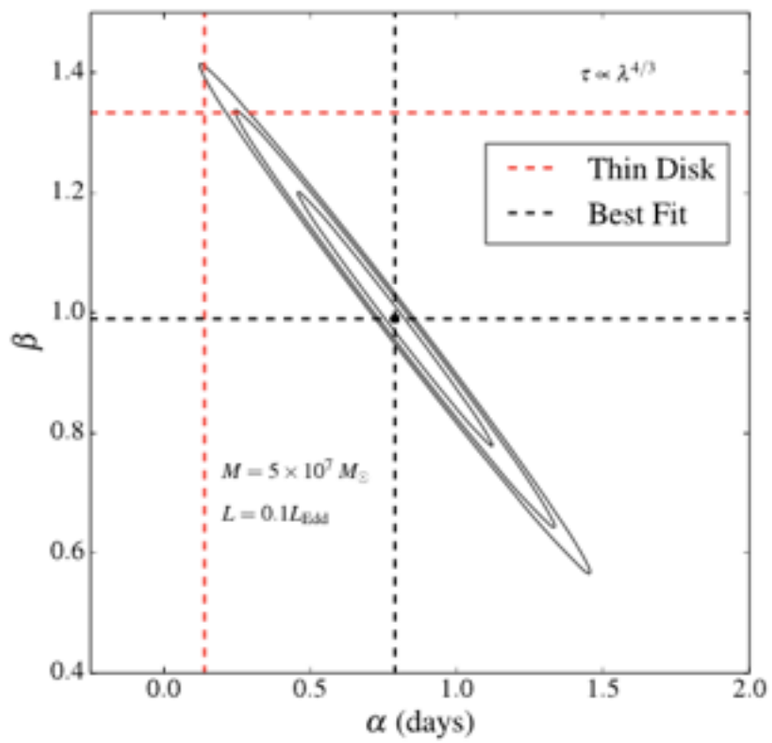
for a classical geometrically thin, optically thick disk

see, e.g. Collier et al. (1999), Cackett et al. (2007), Fausnaugh et al. (2016)

KEY AGN STORM NGC 5548 RESULT: DISK APPEARS TO BE A FACTOR OF 3 TOO BIG

- Moreover, X-rays are not well-correlated and not the driving lightcurve (Starkey et al. 2016, Gardner & Done 2016)
- Enhanced u-band lag may indicate contribution from Balmer continuum (Edelson et al. 2015, Fausnaugh et al. 2016)

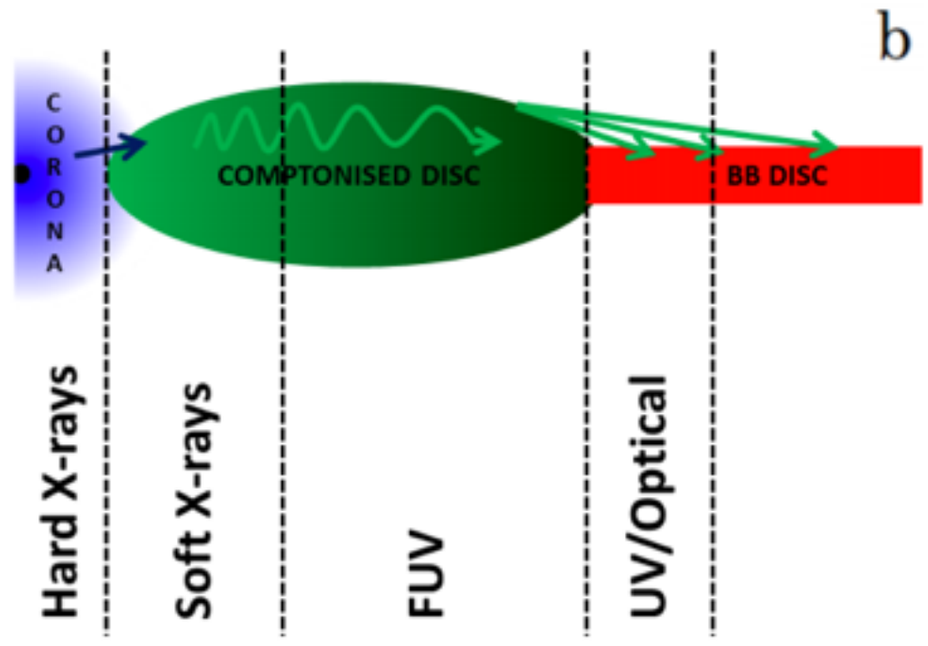




Fausnaugh et al. (2016)
(see also McHardy et al. 2014; Edelson et al. 2015)

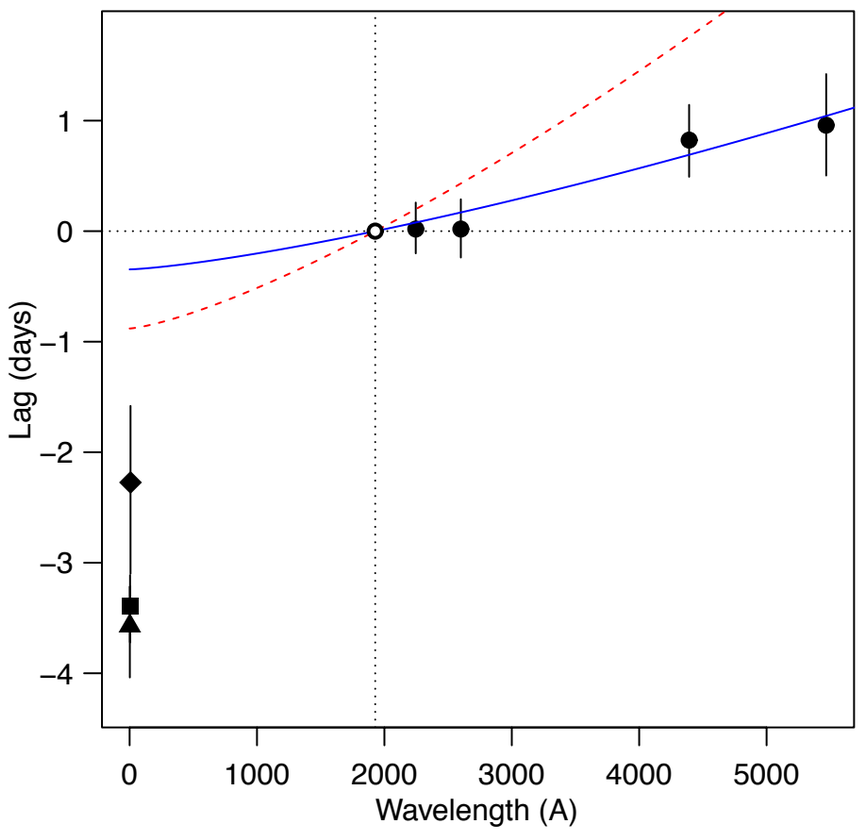
WHY IS THE DISK TOO BIG?

- Contribution of broad lines to photometric bands will enhance lags (e.g. Chelouche et al. 2013), but, not a large effect in NGC 5548 (Fausnaugh et al. 2016)
- BLR diffuse continuum lags (Korista & Goad 2001 - see more from Mike later)
- Gardner & Done (2017) suggest there is a puffed-up Comptonized disk between X-ray emitting region and UV/optical region
- Inhomogeneous disk (Dexter & Agol 2010)
- Tilted inner disk (Starkey et al. 2016)



NGC 4151 WITH SWIFT

- Campaign from early 2016 (Edelson et al. 2017)
- 6 hour sampling (!!) for 69 days (319 observations)
- > 3-day lag from X-ray to UV, but, < 1-day lag from UV to optical

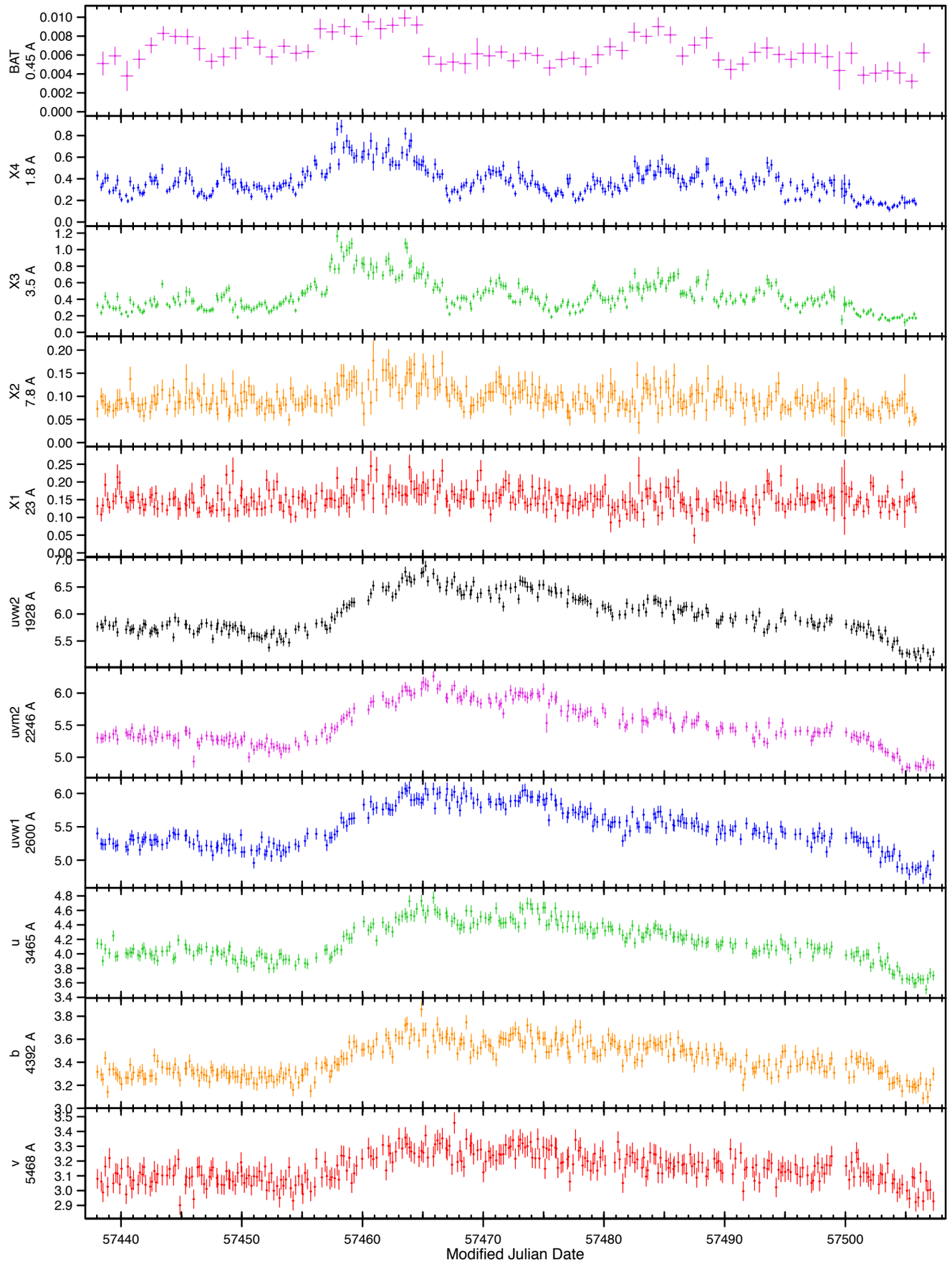


Hard X

4 X-ray bands

UV

V



NGC 4593 WITH SWIFT, HUBBLE AND KEPLER

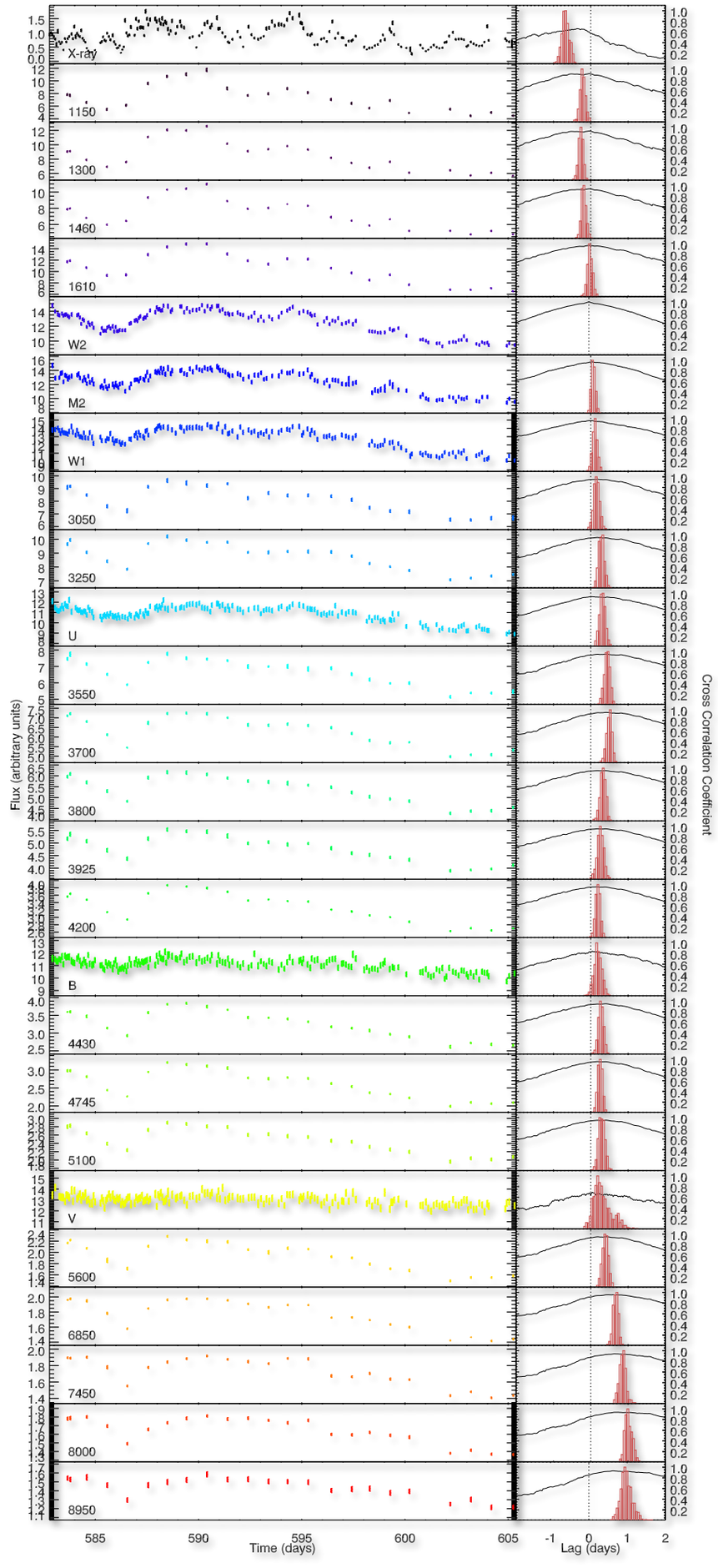
- NGC 4593 was in the Kepler field of view from July - October 2016 (PI: Edelson)
- Visibility overlapped with *Swift* & *HST* for July 2016 only (unfortunately safe-mode ultimately limited *Kepler* overlap even further)
- *Swift* gives high cadence, high S/N lightcurves (~200 obs over 23 days; PI: McHardy, see his talk)
- Monitoring with *HST* once per day for 27 days (PI: Cackett)

Major advantages to this approach:

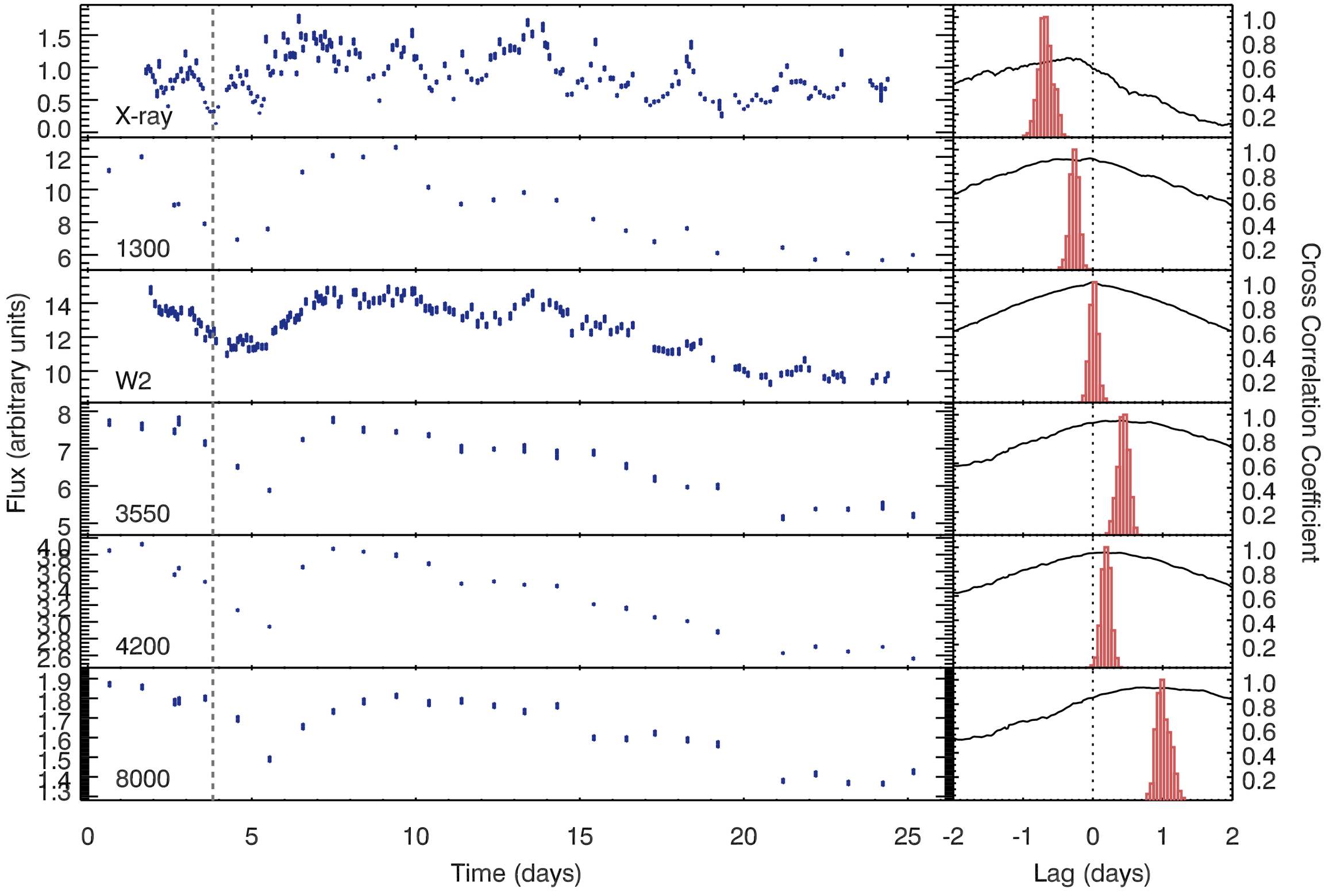
- Low-resolution *HST* spectroscopy allows to cleanly pick out continuum bands over a wide wavelength range
- In one orbit we get G140L, G430L and G750L covering 1100Å to 10000Å (with just a small gap in the near-UV)
- It also covers and resolves the Balmer jump (3646Å) — a key diagnostic of the diffuse BLR contribution

LIGHTCURVES

- We've gotten used to seeing all the beautiful lightcurves at once, along with the CCF and centroid distributions
- So, here we go……

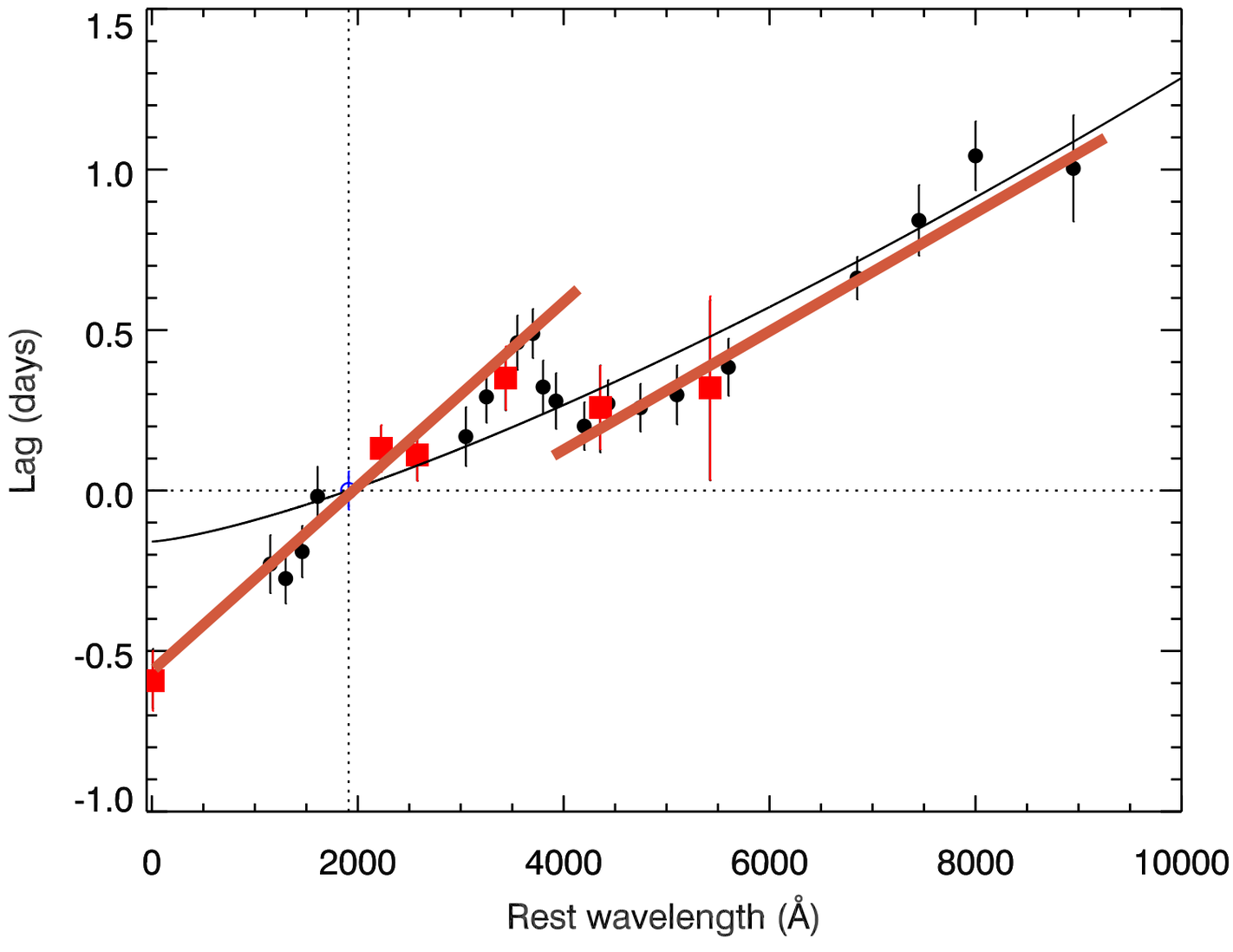


LIGHTCURVES – A FEW SELECT BANDS



WAVELENGTH-DEPENDENT LAGS

- Lags via standard FR/RSS w.r.t. *Swift*/W2
- Clear **discontinuity** around the Balmer jump
- Does ***not*** follow $\lambda^{4/3}$ everywhere



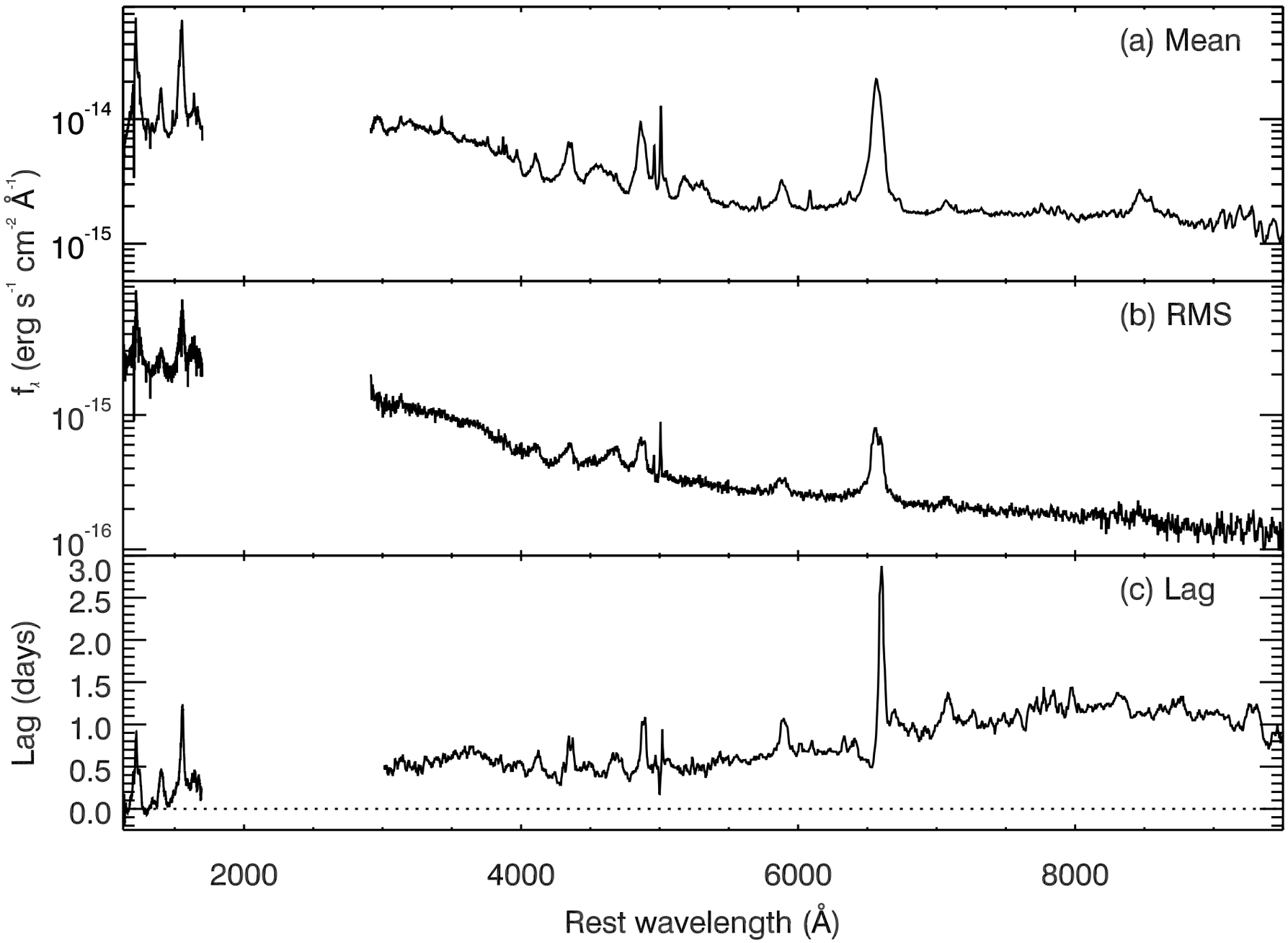
Red: Swift

Black: HST

Blue: Swift/W2

MEAN, RMS AND LAG SPECTRA

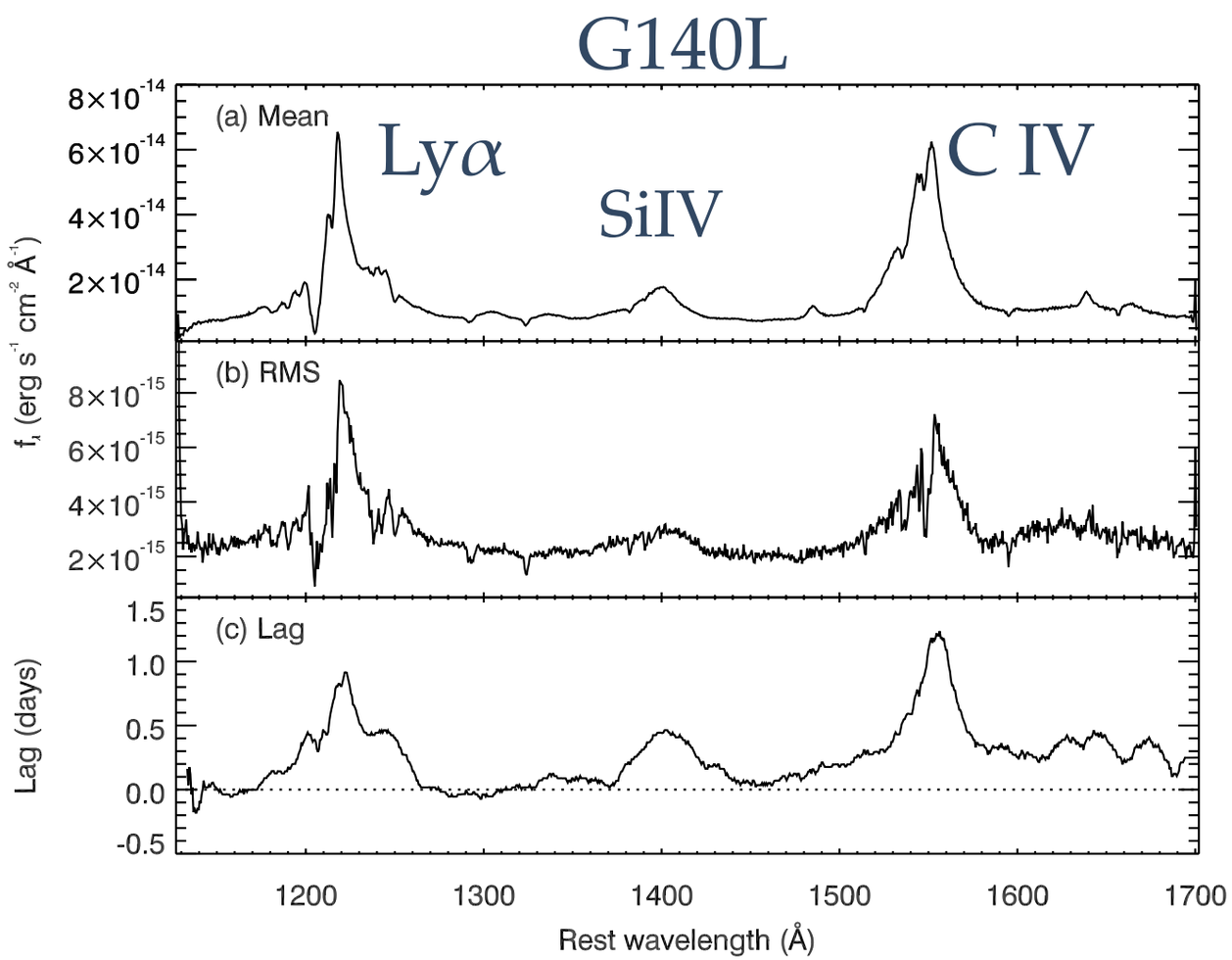
- Calculate lags using ICCF and a sliding box to get a ‘lag spectrum’



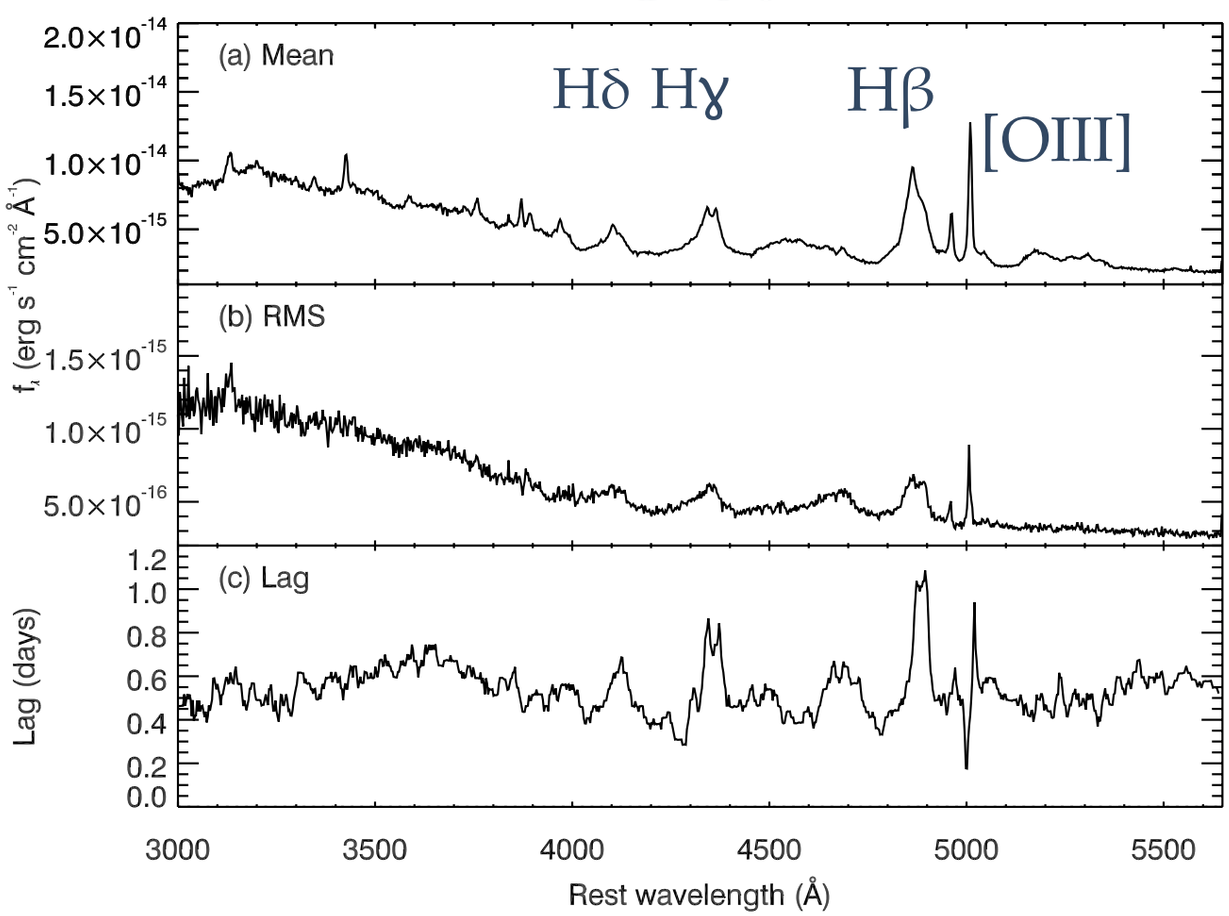
MEAN, RMS & LAG SPECTRA

- Lots of work still to do on emission line reverberation with these data

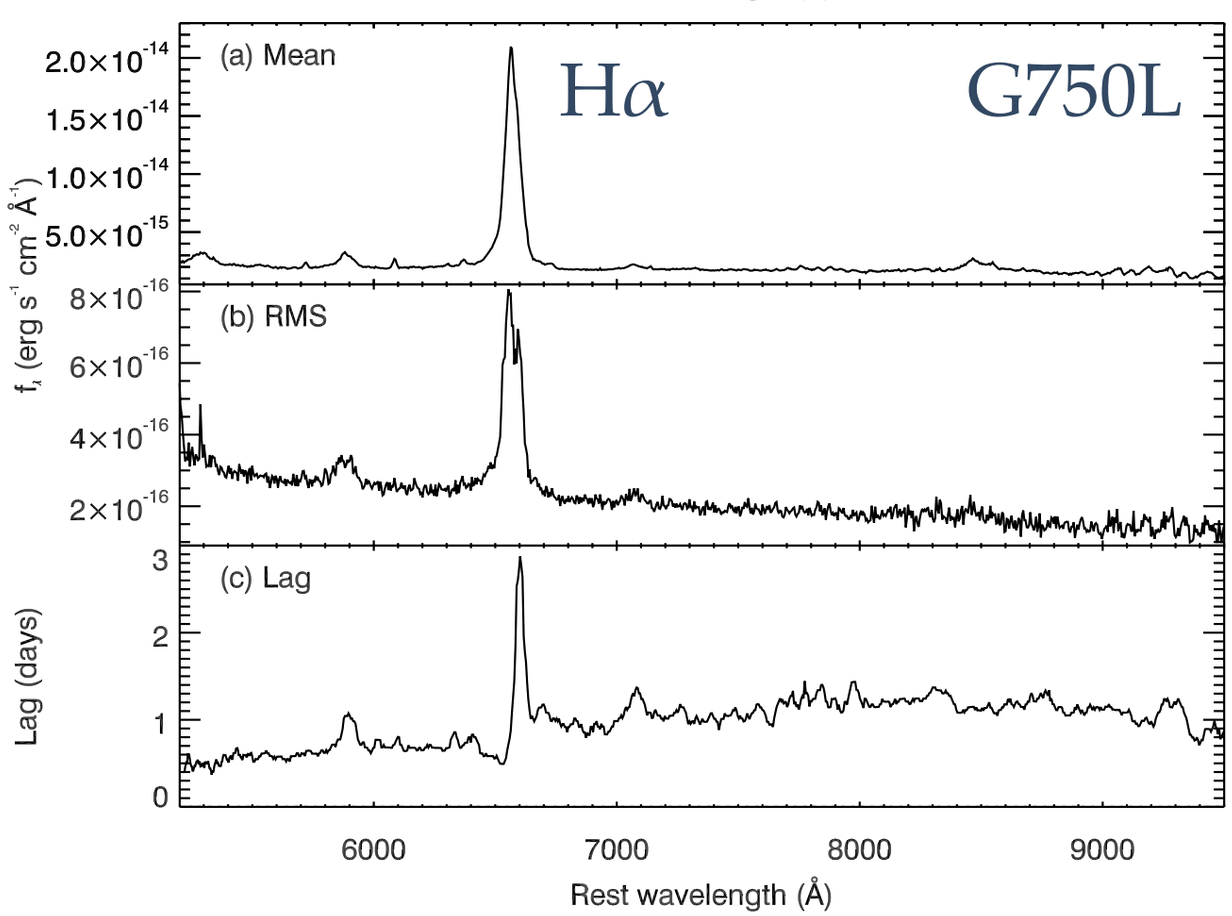
G140L



G430L

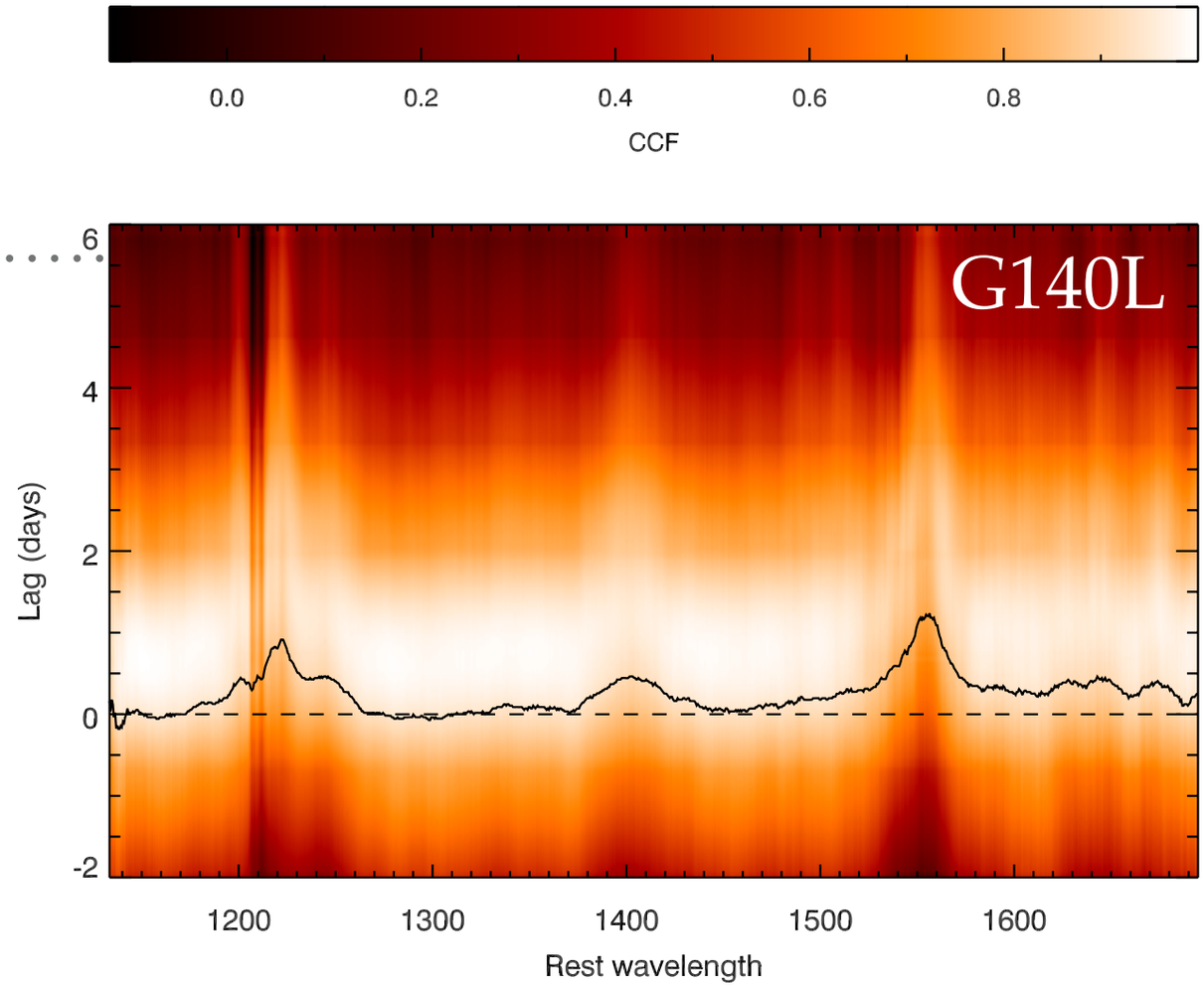


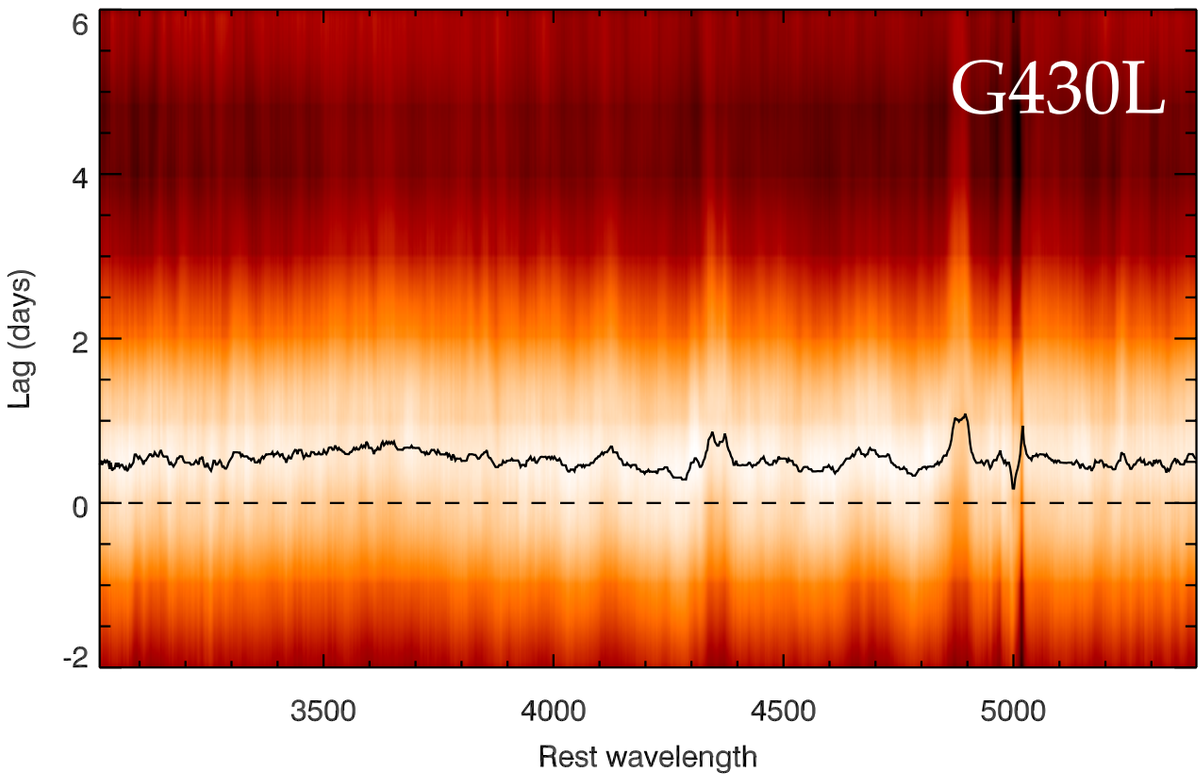
G750L

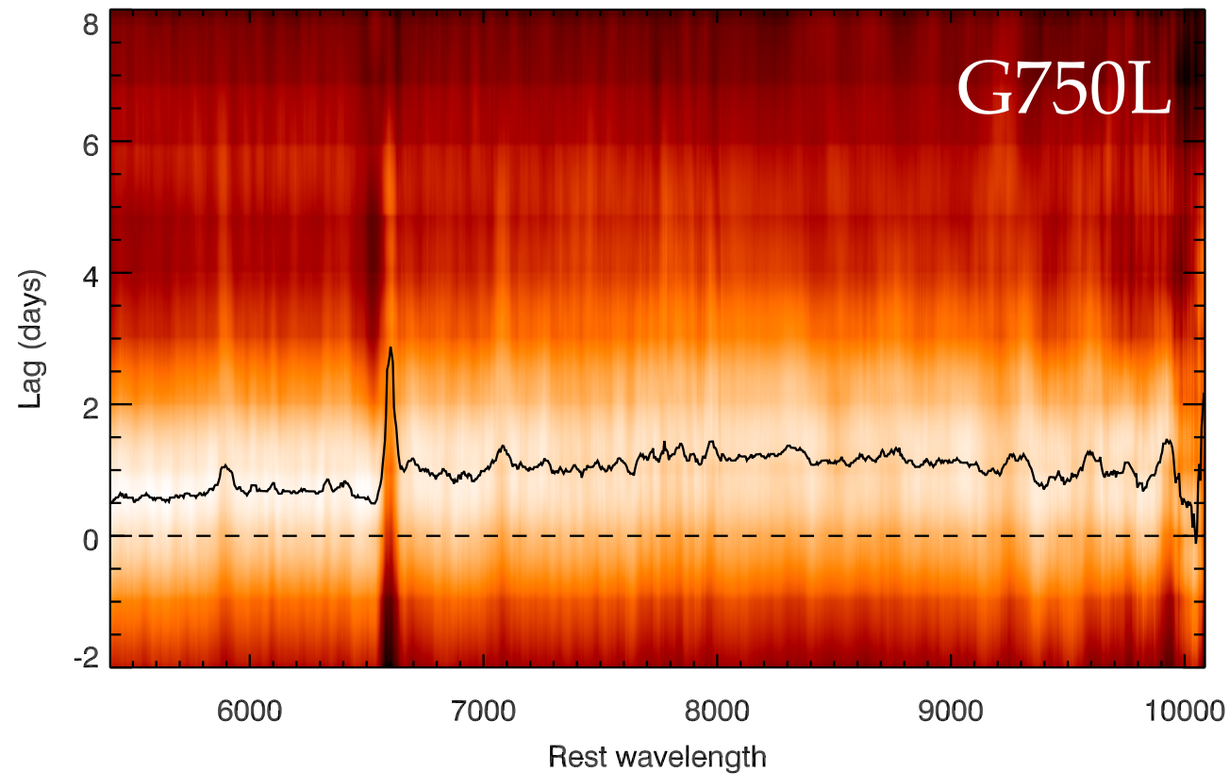


DYNAMIC CCF

- Plot the CCF at each wavelength to create a dynamic CCF

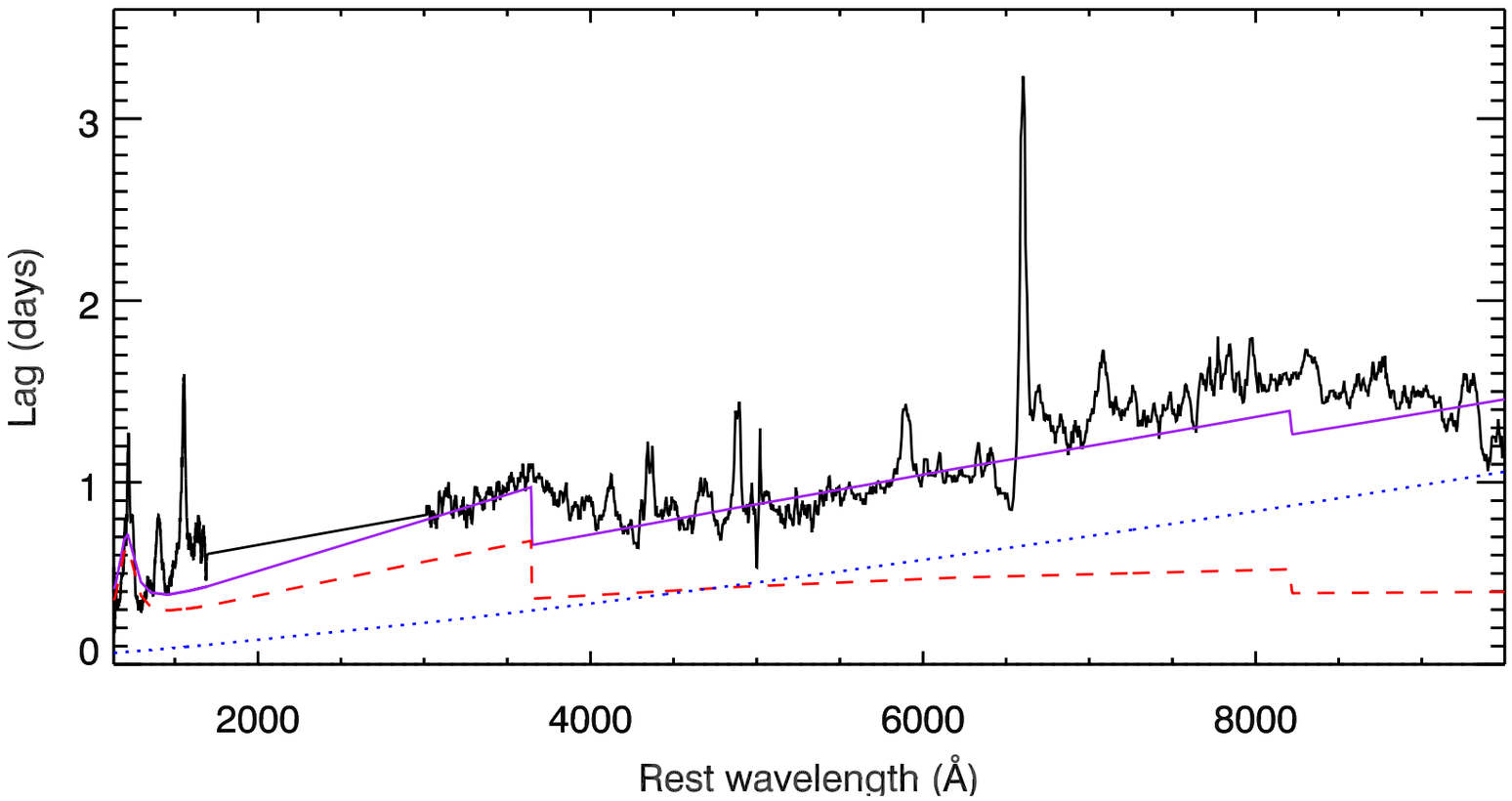






SIGNIFICANT DIFFUSE CONTINUUM CONTRIBUTION TO LAGS

- Lags now shown w.r.t. X-ray
- DC lags dominate shortward of 4000Å
- No X-ray offset when including the DC model
- Disk lags still a factor of 3 larger than expected



- Blue dotted: $\lambda^{4/3}$
- Red dashed: diffuse continuum lags from BLR (model from Mike & Kirk)
- Purple: overall model