AGN accretion disk RM: where we’ve been, where we are, where we’re going

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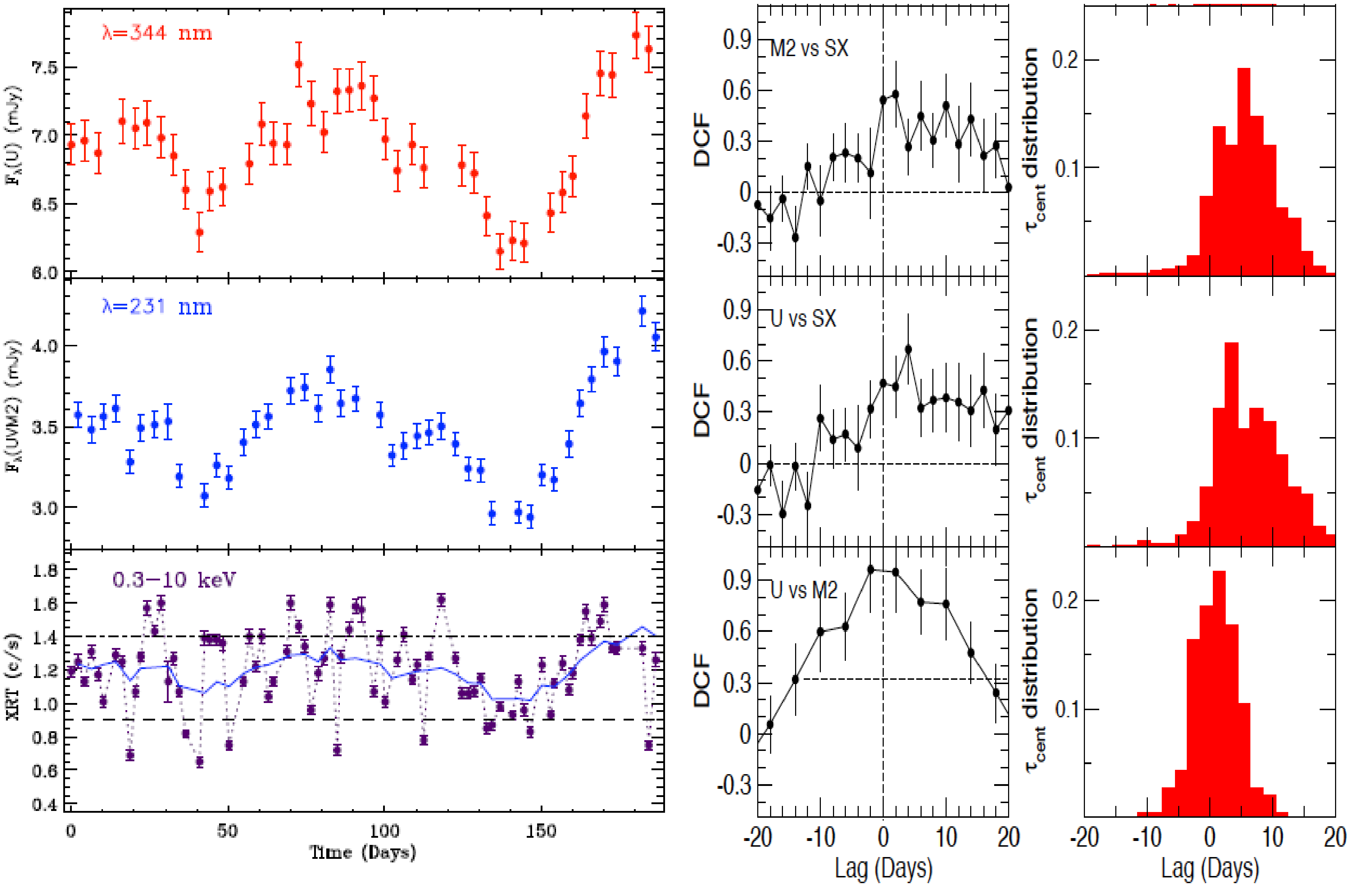
From AGN BLR RM to disk RM

- Blandford & McKee (1982): line variability driven by small opt/UV continuum source, so "light echoes" of the continuum in the lines can be used to constrain the size, structure of BLR
  – pursued observationally throughout the '80s w/unclear results
- Segovia 1987: AGN Watch formed to intensively monitor NGC5548 w/ IUE, ground-based telescopes (64 IUE epochs!)
  – opened a new window on AGN, leading to e.g. M_{BH} estimates
- Also led to trying accretion disk RM using X/UV/opt continuum
  1) corona drives disk variations, so study X/opt correlation, lag
  2) disk hotter inside, cooler outside, study lags within UV/opt
- Early results (through 2014) suggestive of interband correlations with lags in the right direction, **but not definitive** ($< 3\sigma$)

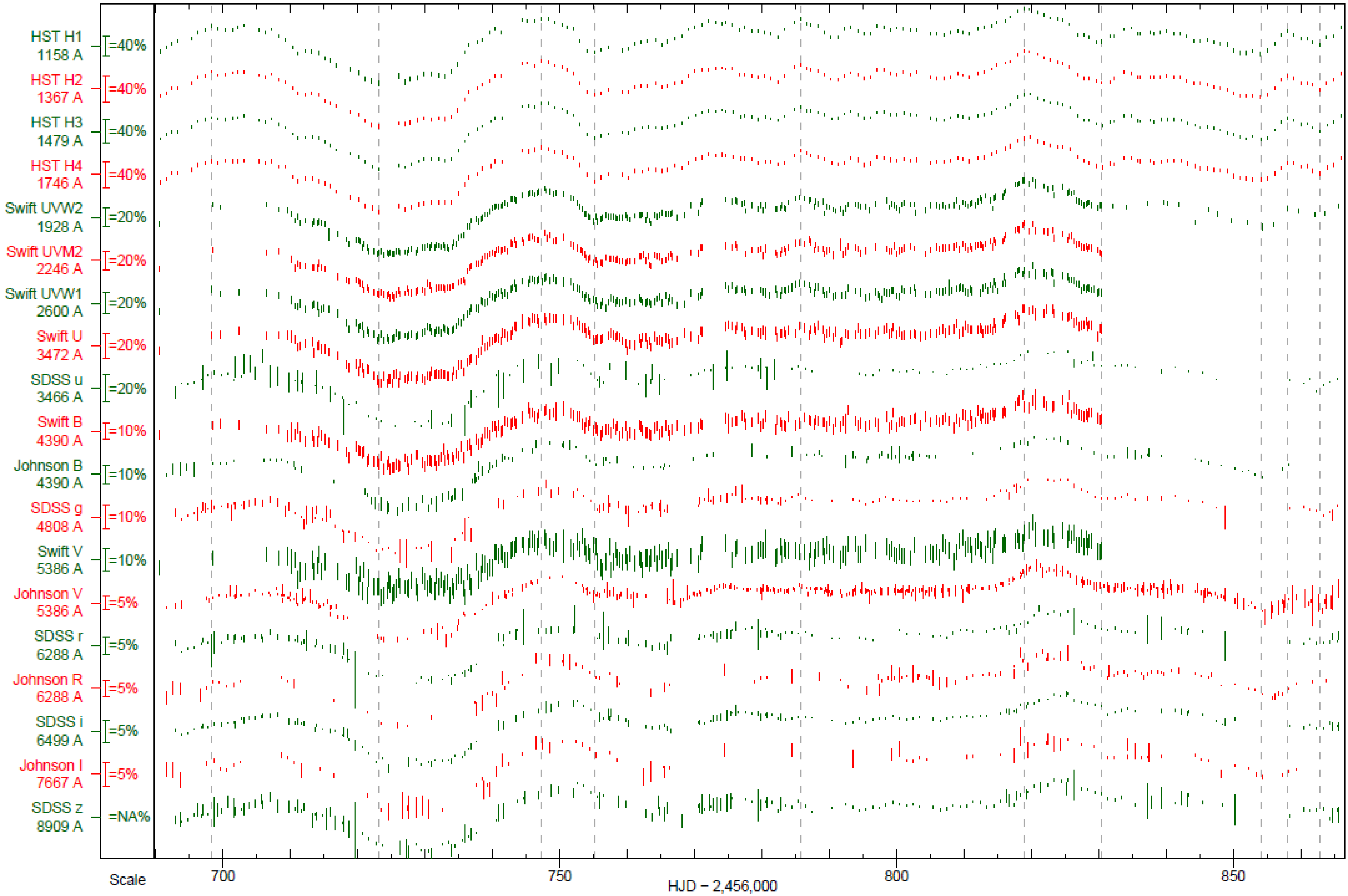
Ex: Ark 120 (Gliozzi et al. 2017, MNRAS, 464, 3955)



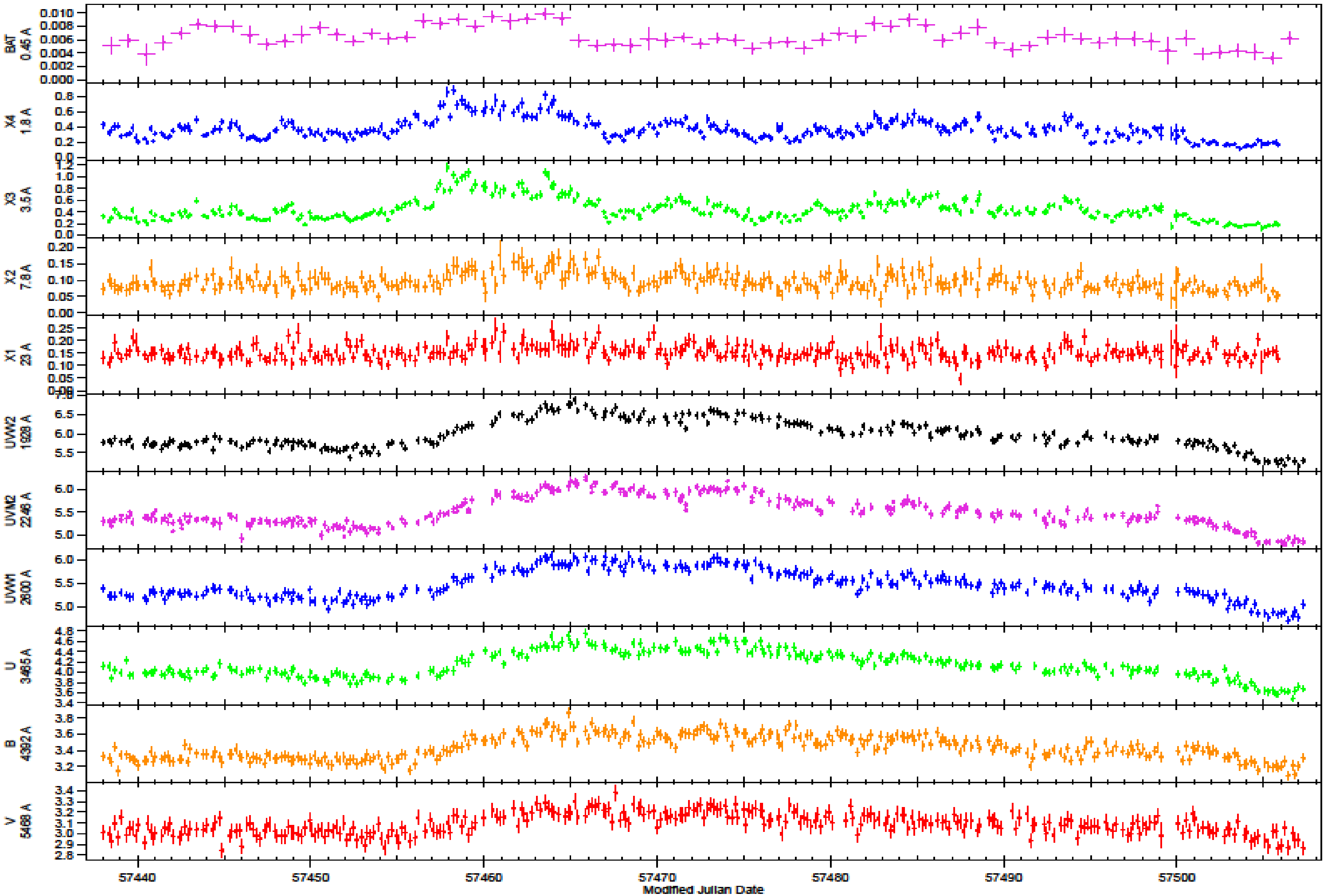
Swift opens a new era in disk RM

- Early (inconclusive) expts measured X-rays with one instrument (ASCA, RXTE), opt or UV with another (ground-based, HST): highly inefficient and ineffective
- Swift combined these but not optimally used in early years; only 1 or 2 UV/opt bands, low cadence
- Breakthrough: Swift director Neil Gehrels approved full use of UVOT filter wheel to get 6 bands in opt/UV
  - Courageous decision, opposite of XMM UVOT usage
- This is opening up a new era in AGN monitoring
  - Not only our group, but others are now doing this (e.g. Fairall 9, Lohfink & Reynolds 2016)

NGC 5548 full campaign light curves

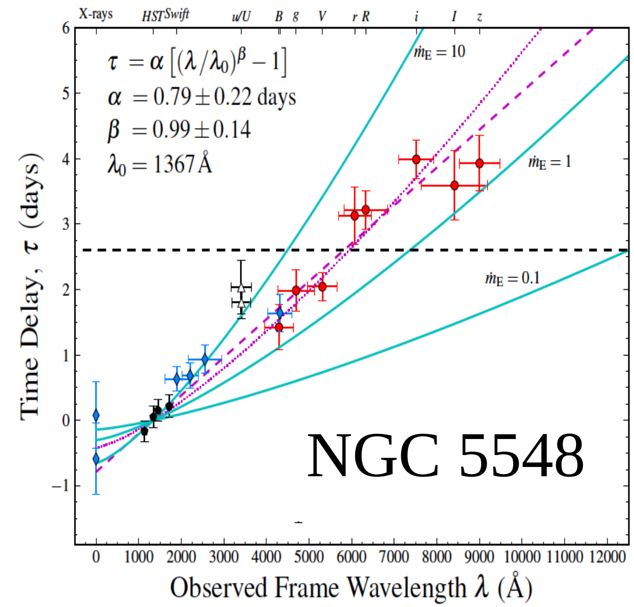


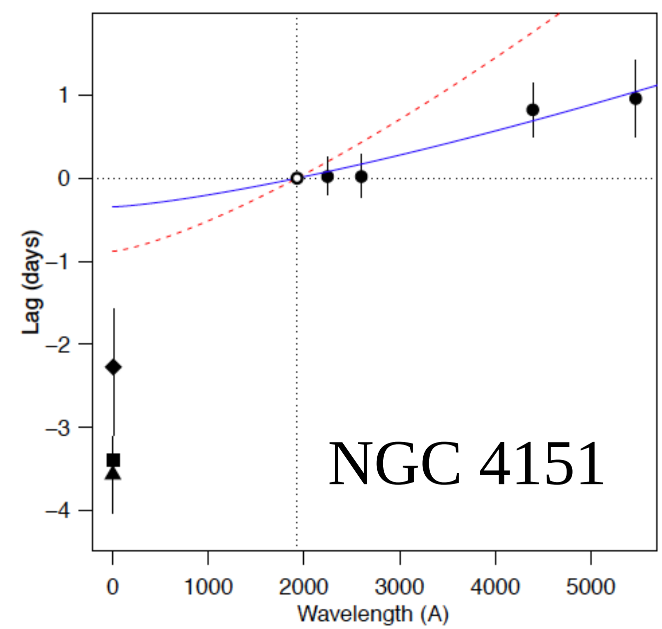
NGC 4151 (Swift only) light curves



Lag vs. Wavelength Fits

- Top panel shows NGC 5548 data
  - Both fits show $\tau \propto \lambda^{4/3}$
  - U band not included
- Bottom panel: NGC 4151 data
  - Red is full data set, very poor χ^2.
  - Blue is just to UV/optical, acceptable χ^2 but massively overshoots X-ray data
- Bottom line is these data cannot be fitted by standard S-S thin disk





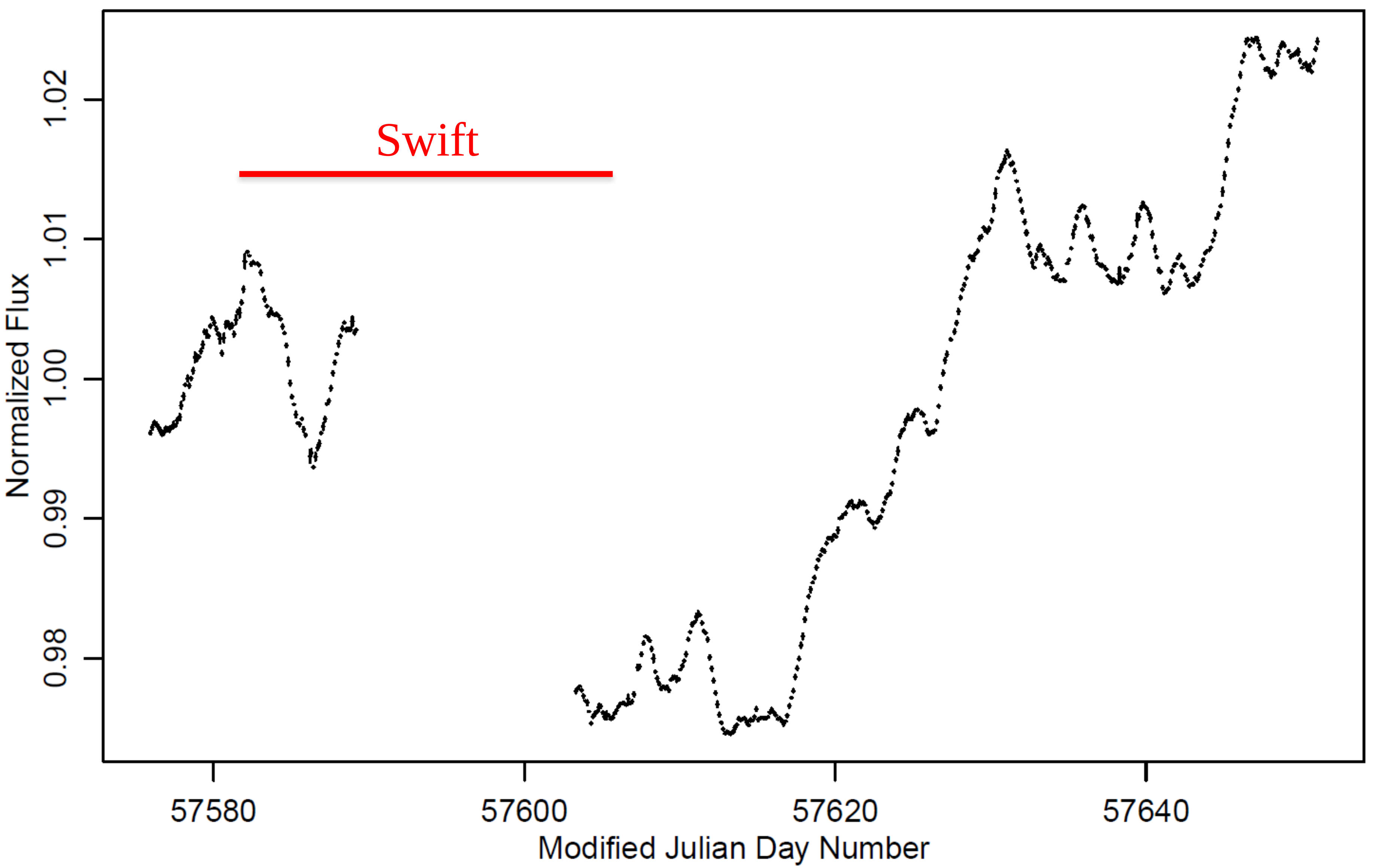
Summarizing NGC5548, NGC4151 results

- We now understand how to properly execute disk RM
  - Key: Swift's intensive coverage in time, wavelength
- In UV/optical, wavelength-lag follows Shakura-Sunyaev predictions, but disks a factor of ~3 too large
- U-band excess lag neatly explained by Korista & Goad (2001) as diffuse continuum from the BLR
- Initial disk RM results established, we now want to expand the parameter space we are testing
  - expand to higher L/L_{Edd} – Ian's focus
  - expand to higher M_{BH} – my focus

Current/recent disk RM campaigns

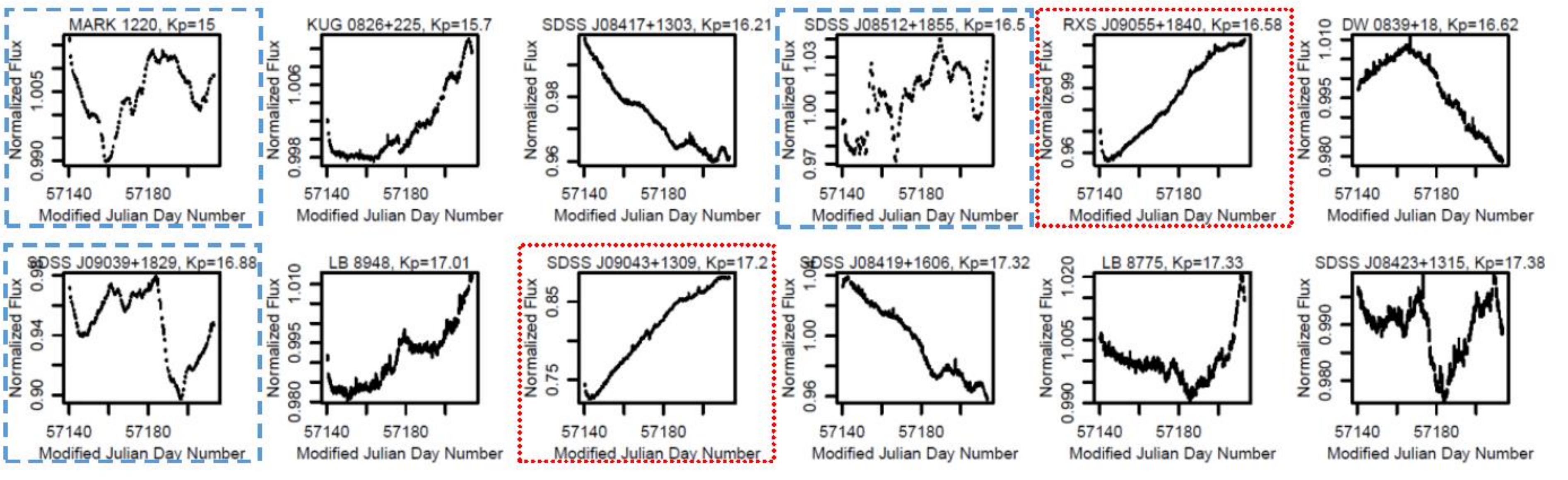
- NGC 4593 Swift/HST/Kepler/AstroSat
  - Observations occurred over a year ago, papers are being written by Ed (HST) and Ian (Swift)
  - Most K2 data wiped out by two spacecraft anomalies
- Mrk 509 Swift/ground-based
  - Factor of ~2 higher M_{BH} than NGC 4151, NGC 5548
  - Everything proceeding nominally, ends mid-Dec.
- Mrk 110 Swift/ground-based/AstroSat (?)
  - Ian in charge, he has details, Nov ‘17-Jan ‘18 (?)
  - Also a high L/L_{edd} target

NGC 4593 K2 and Swift light curves

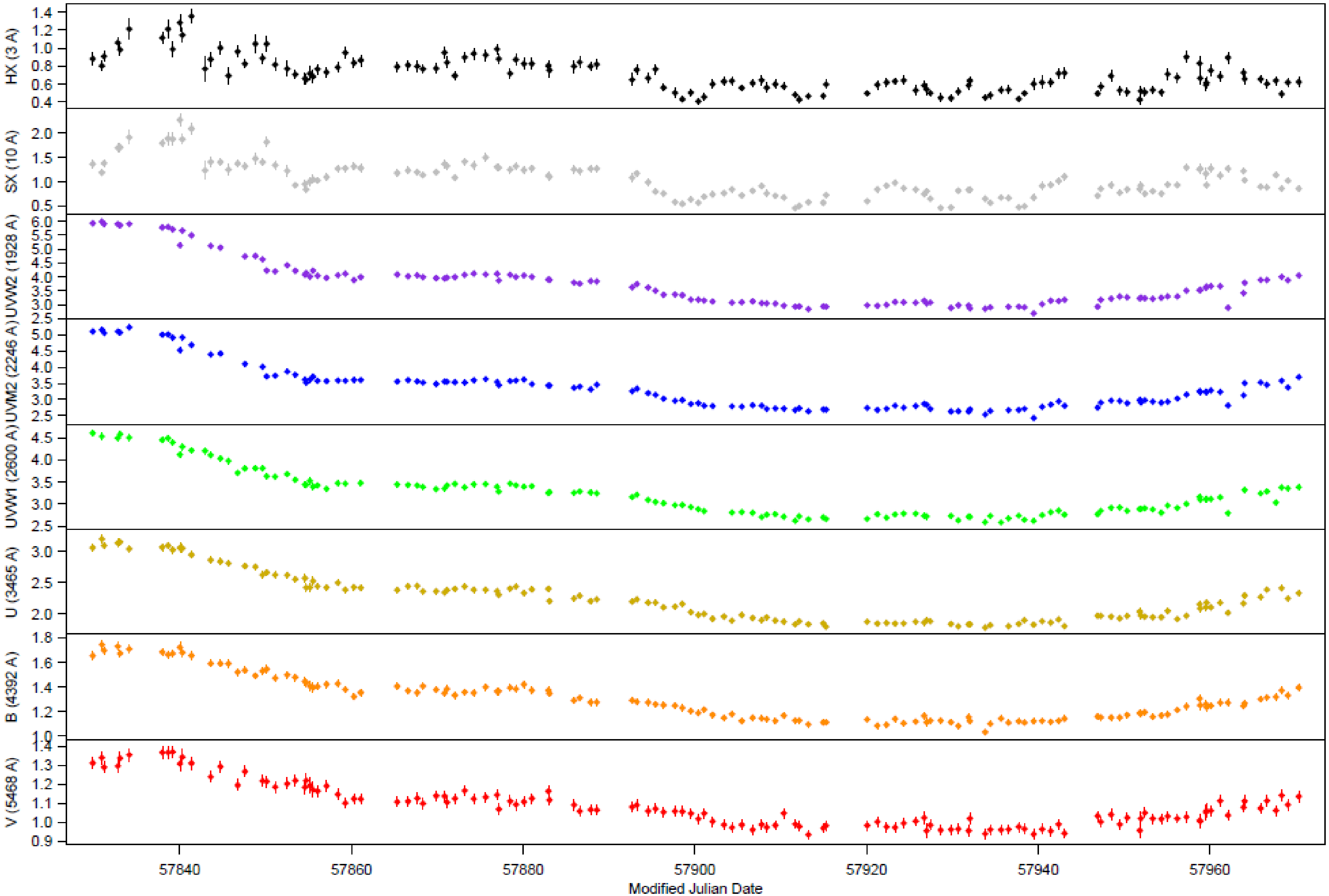


Kepler systematic errors

- Differential Velocity Aberration (DVA): 2nd order relativistic effect causes field to "expand" or "contract" as a function of position in orbit around Sun
- Induces apparent long-term signal in 80 day K2 LCs
- What is real? What is instrumental?
- May be able to calibrate with ground-based R+I

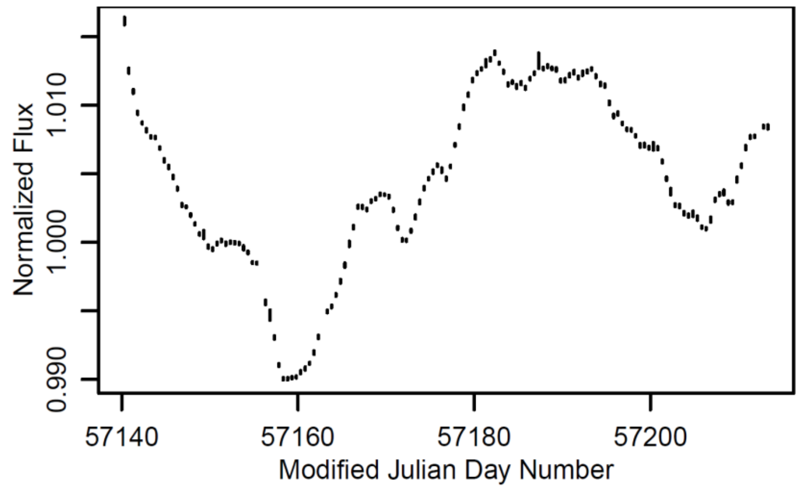


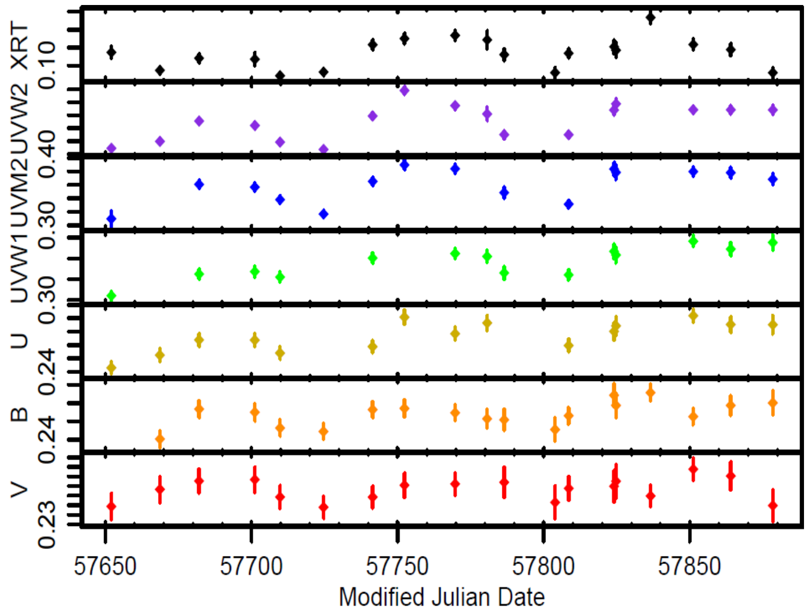
Mrk 509 Swift light curve to date



Mrk 1220

- NGC 4593 K2 campaign failed, we do have another opportunity.
- C16 (7 Dec ‘17-25 Feb ‘18) is a forward-facing pointing for which simultaneous ground based and Swift monitoring is possible
- Mrk 1220 is the brightest known Seyfert 1 in the field, also done in C5 (back-facing)
- Keith has LCO time for this, we will submit K2 “white paper” within the next 2 weeks
- Participation open to all so please let me know if you are interested





Ark 120 solves many of our problems

- Unlike all previous disk RM targets, Ark 120 appears to suffer from NO apparent line of sight (los) absorption
  - Vaughan (2004) finds it has the lowest los absorption of >100 AGN surveyed by XMM RGS, factor of ~10 lower than typical
- Also 1-1.5x10^8 M_S depending on the source
  - Luminous AGN have lower BLR filling factors
- All of this makes it ideal for disk RM because it is much less likely to suffer another holiday

Example: Ark 120 (Gliozzi et al. 2017 MNRAS, 464, 3955)

Swift Cycle 10 proposal abstract:

We propose to monitor for 6 months the prototypical "bare" AGN Ark 120 with the UVOT and XRT. A simultaneous study of UV, optical, and X-ray variability in AGN is one of the most effective tools to shed light on their central engine. The selected target is ideal to investigate correlated flux variation in different energy bands because: 1) it is a bright "clean" system without warm absorbers or jets, 2) it is highly variable on all time scales over the entire spectrum, 3) its large BH mass coupled with low accretion rate offers the ideal conditions to produce a tight X-ray/optical correlation. The proposed study will provide crucial information on the origin of variability and the interplay between disk and corona in AGN.

Ark 120 campaign basics

- Visible to Swift, ground based telescopes for 9 months
  - 23 July – 26 April (following year), ~1 day a month lost due to lunar interference (near ecliptic plane)
  - Also visible to HST for 8 months in this period
- Planning a 2 year campaign, 23 Jul 2018 - 26 April 2020
  - daily monitoring, 6 filter UVOT + XRT in PC
  - Will yield ~520 cadences over 2 years w/3 mo gap in middle, sensitive to lags over >10 larger range
  - Submit parallel HST proposal
- As always, participation will be open to all, however I am asking that anyone on this proposal not submit a Swift Cycle 13 proposal (ex. Ed Cackett)

Over the very long term

- Now have a clear idea of how to perform disk RM
- How should we proceed? Two schools of thought.
- Study range of M_{BH} or L/L_{Edd}?
  - We need to do both
- This requires identifying best candidates in each range
  - High L/L_{Edd} targets (rapidly variable) ID'ed from TESS (Michael's talk)
  - But ID'ing suitable high M_{BH} targets will be harder
- We need to identify a few (more) really high mass, decently variable AGN disk RM targets
- Will require long term (years) ground-based monitoring