Searching for X-ray eclipses in NGC 6814 using dense optical/UV to X-ray monitoring with *Swift*

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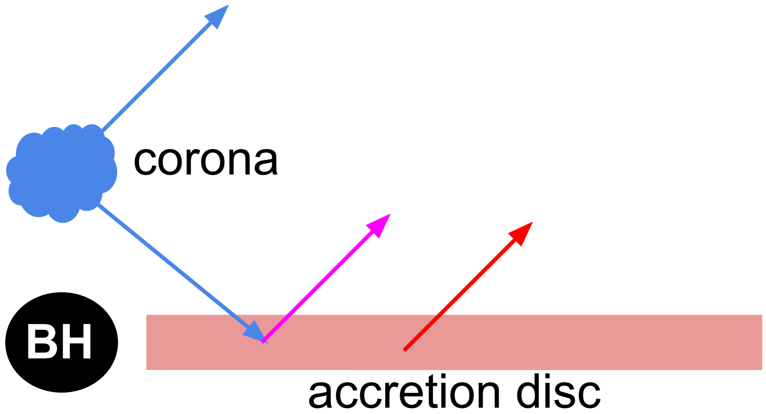
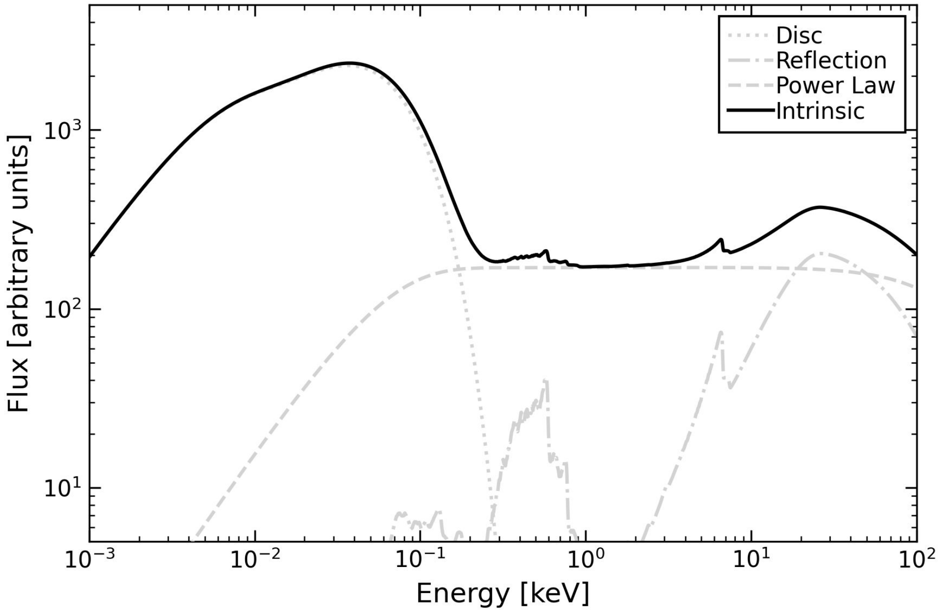
<u>Collaborators:</u> Luigi Gallo, Ben Pottie, Jon Miller, Elias Kammoun

26 June 2023
The Restless Nature of AGN: 10 years later

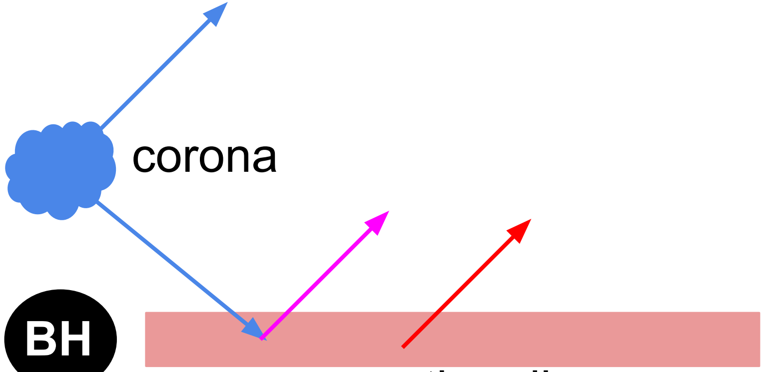
AGN Central Engine

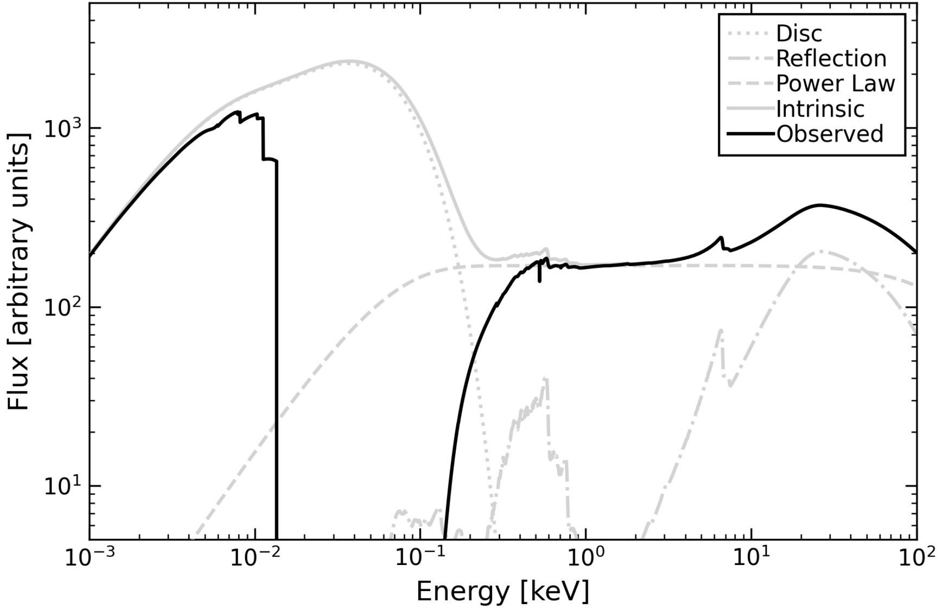




AGN Central Engine

Milky Way





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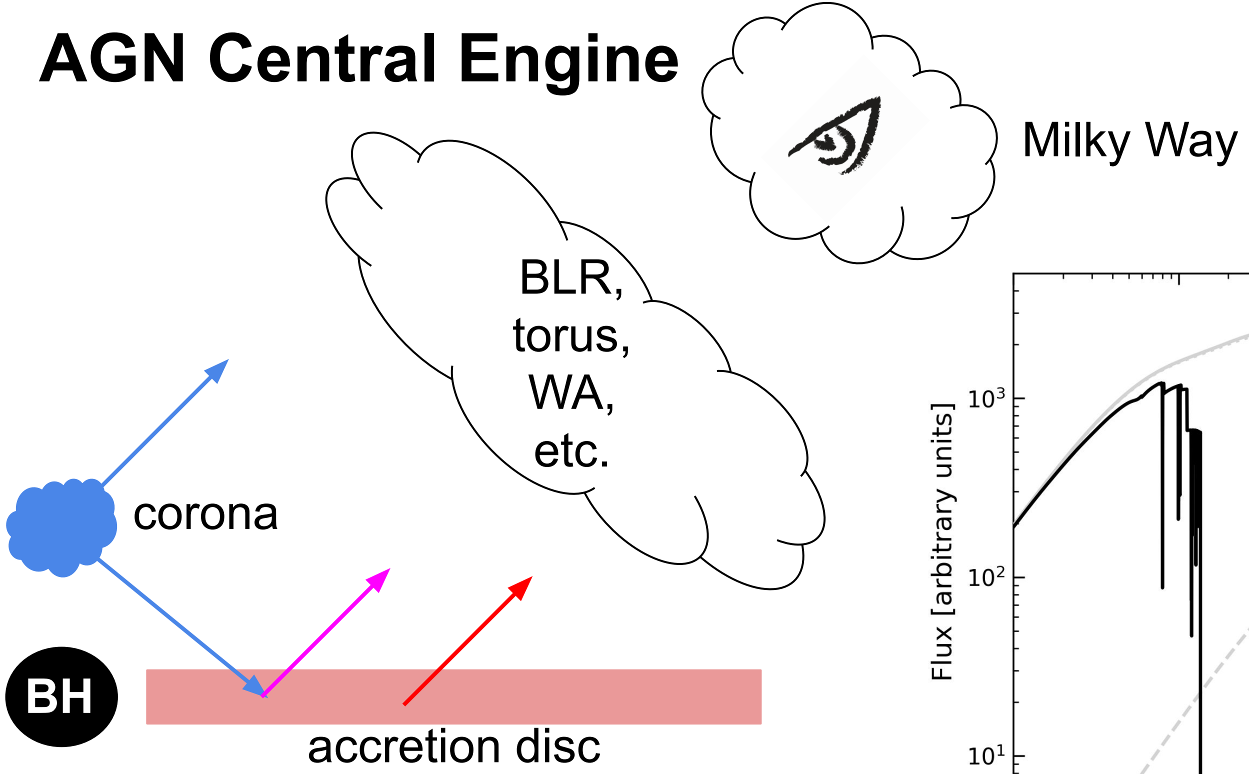

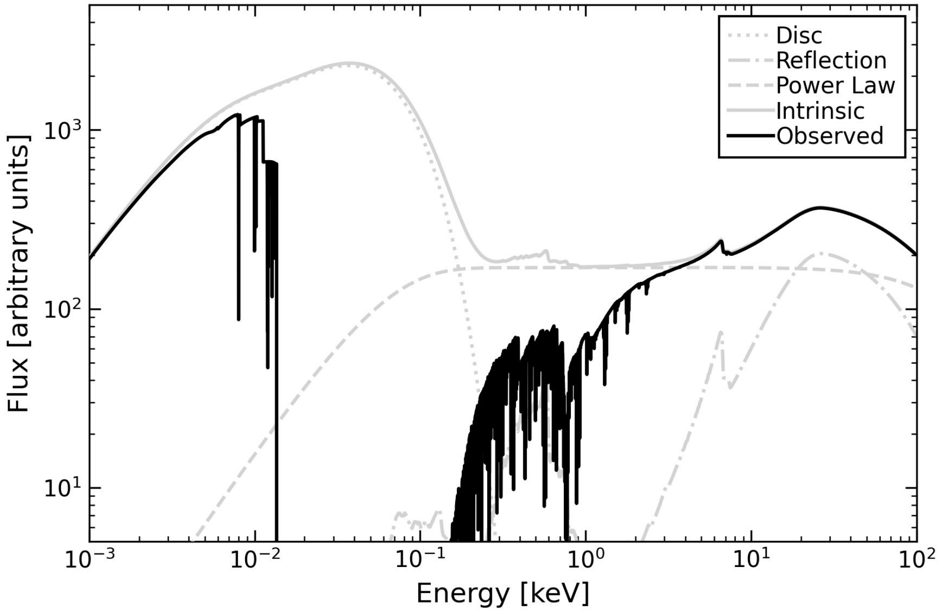

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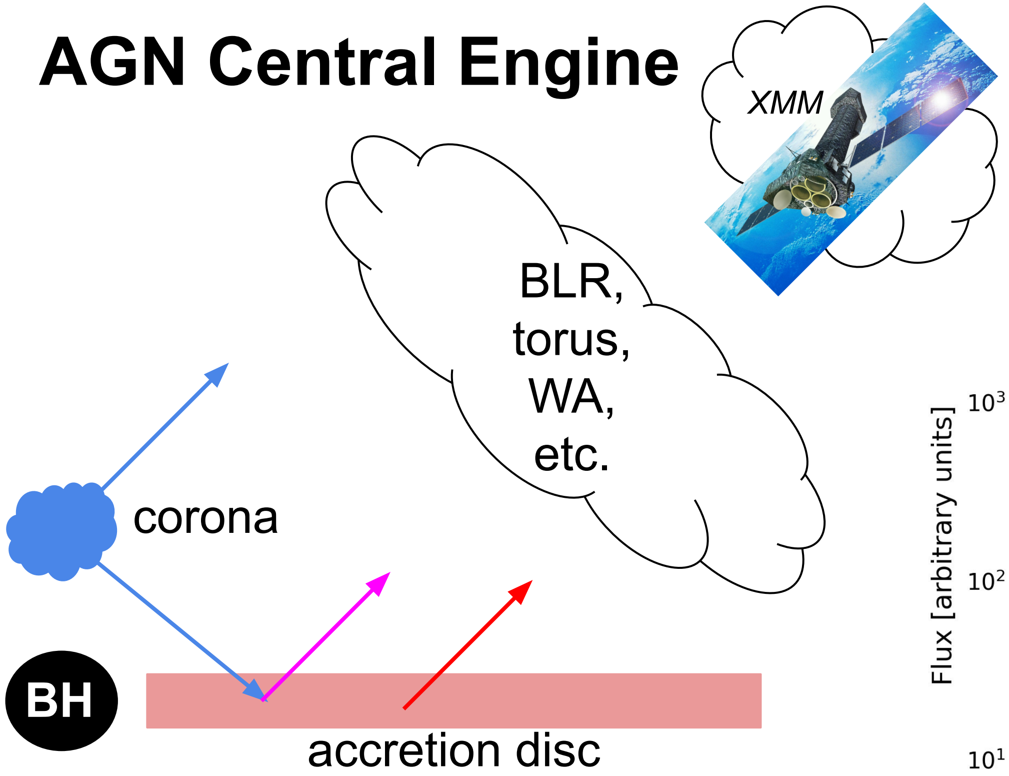

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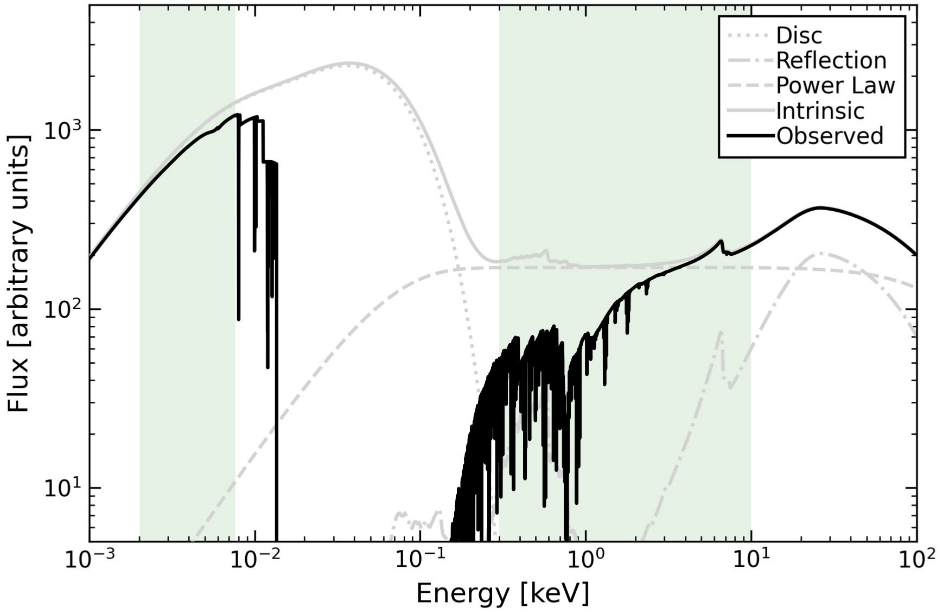
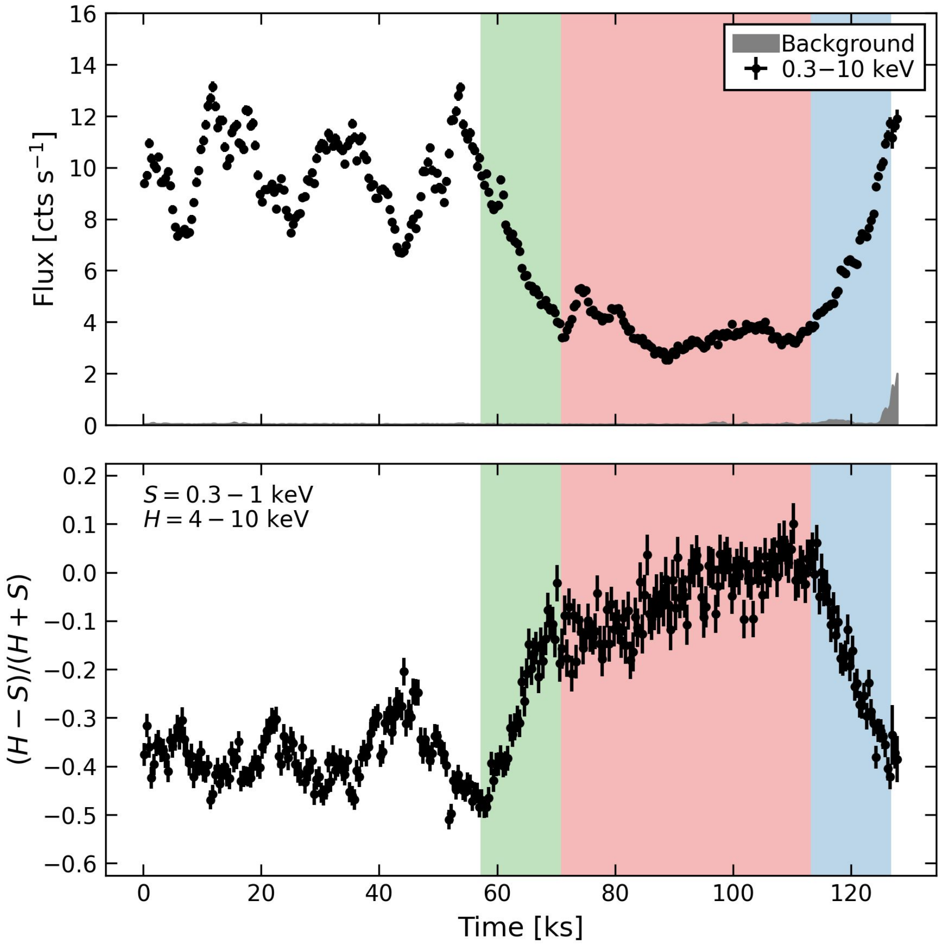


The X-ray Eclipse

- Rapid occultation event starts at ~55ks and lasts ~70ks:
  - Decrease in flux + spectral hardening lasts ~13.5ks (ingress)
  - Flux and hardness 'plateau' for ~42ks
  - Increase in flux + spectral softening lasts ~13.5ks (egress)
- Ingress & egress are exactly the same duration, and the source returns to its pre-eclipse flux & spectral state



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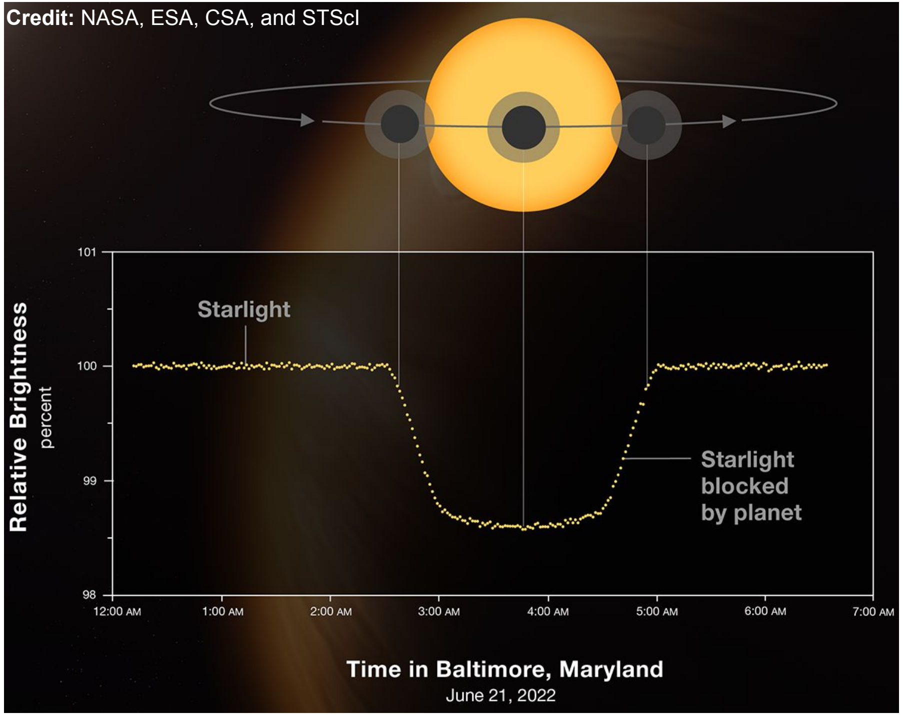
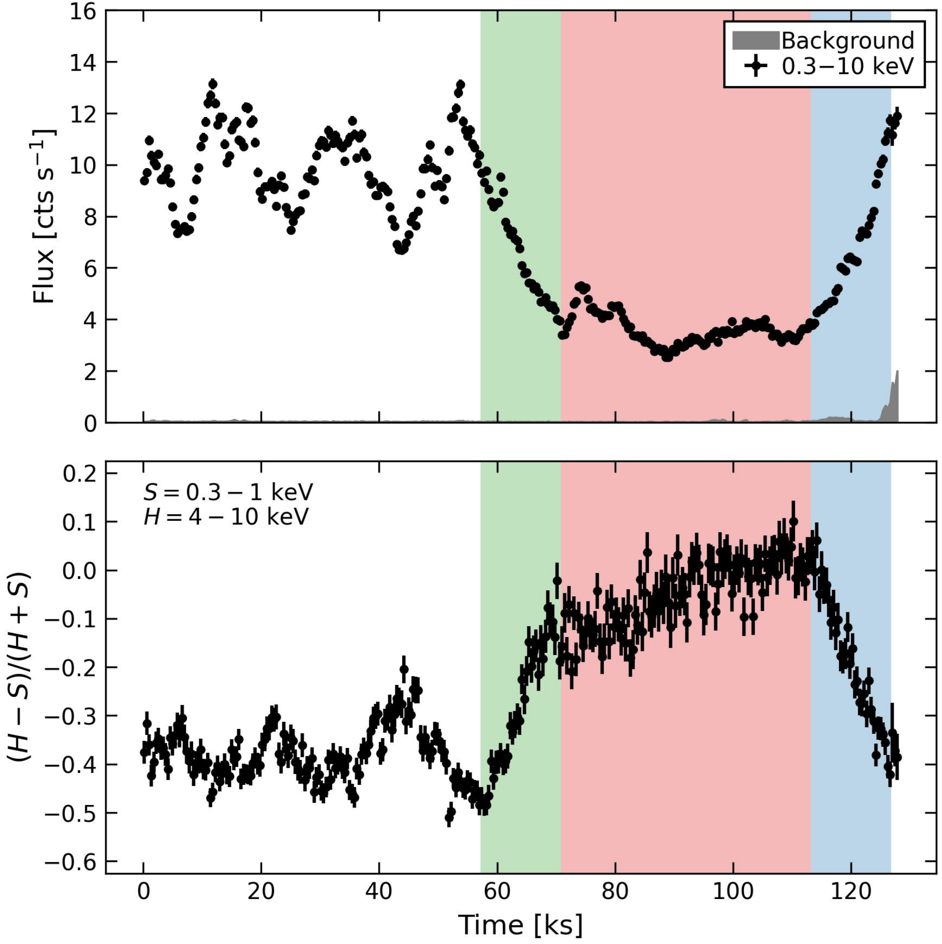
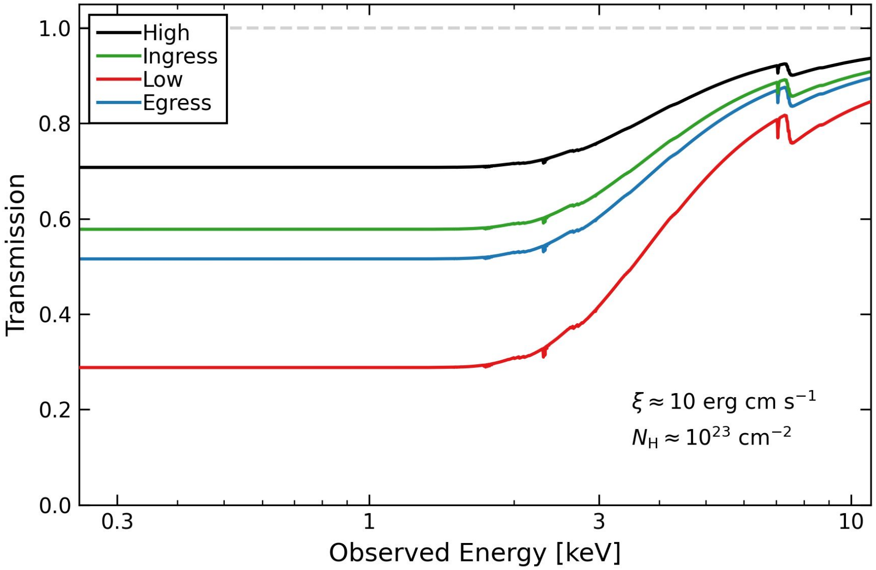
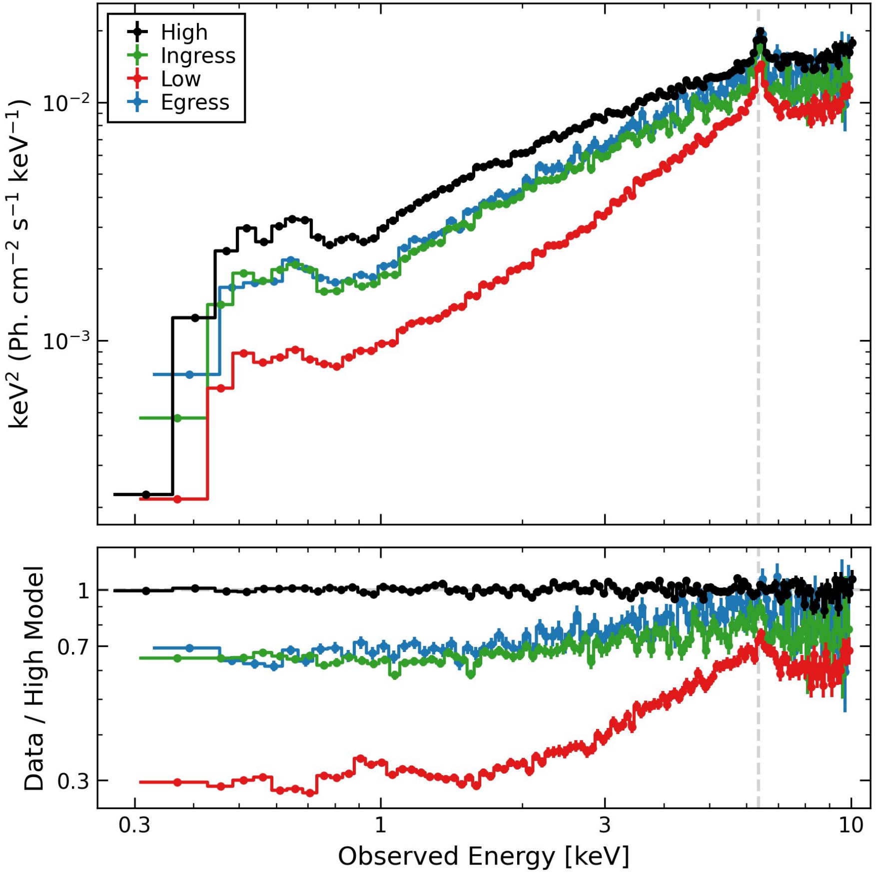




The X-ray Eclipse

- Partial covering of the X-ray region is required in all epochs, increases from: f_{cov} = **0.3 → 0.4 → 0.7 → 0.5**

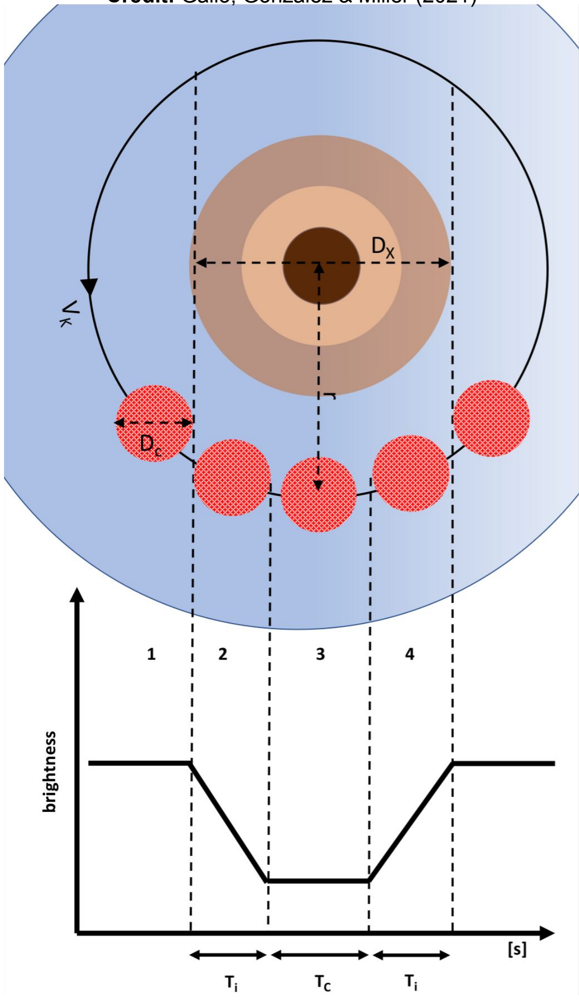




The X-ray Eclipse

BLR spans $\sim 10^{3\text{–}5}\ r_g$
$M_{\rm BH} \approx 2\times10^{7}\ M_\odot$
$L_{\rm X} \approx 2\times10^{42}$ erg s^{-1}

Credit: Gallo, Gonzalez & Miller (2021)



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- Obscurer properties are:

$$r^{5/2} = (GM_{BH})^{1/2}\, L_X \Delta T (N_H \xi)^{-1}$$
$$r \approx 4\times10^{15}\ \text{cm} \approx 2700\, r_g$$

$$n_e = L_X (r^2 \xi)^{-1} \approx 10^{10}\ \text{cm}^{-3}$$

$$D_c = N_H n_e^{-1} \approx 10^{13}\ \text{cm}$$

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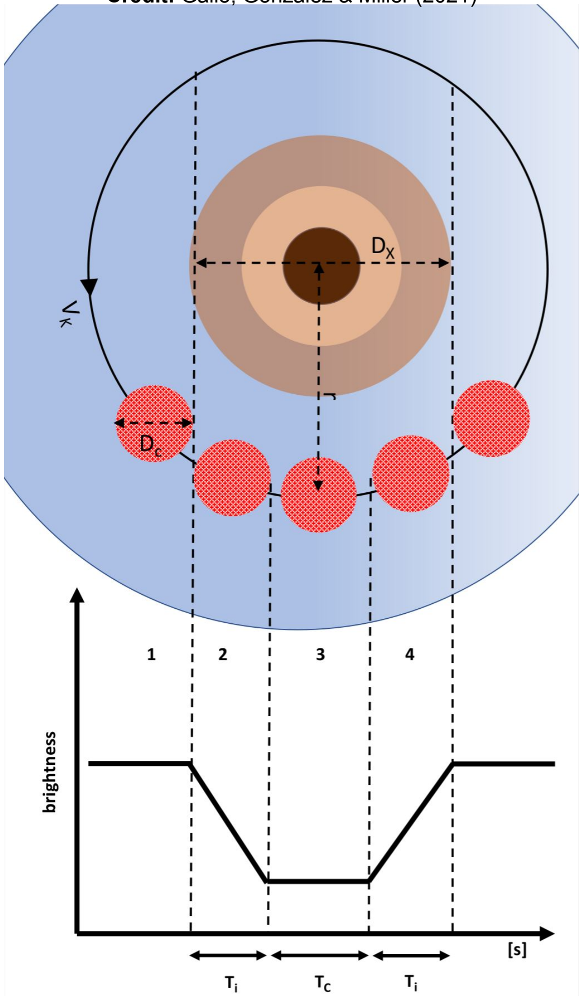

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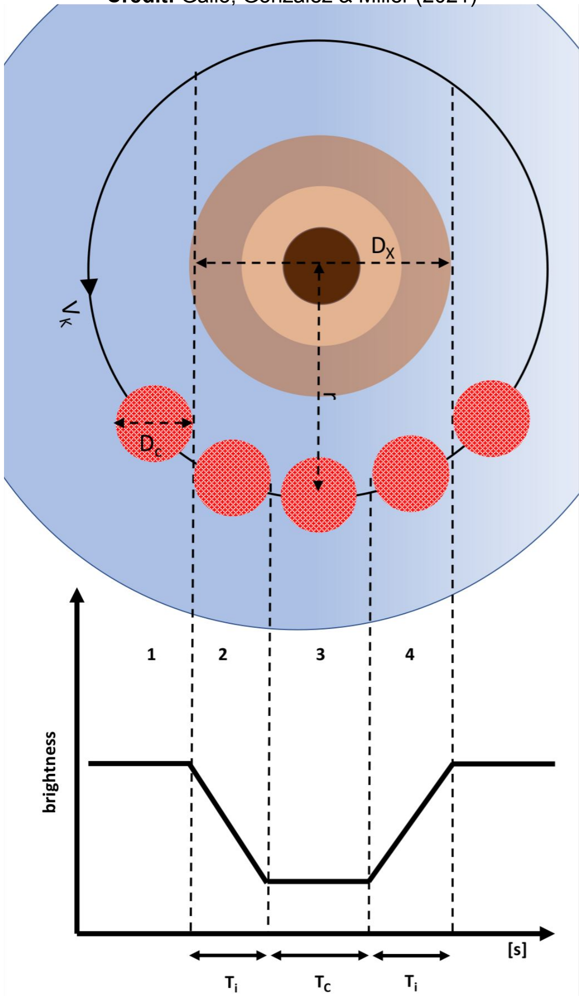

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- Fe K emission line may originate from the same material:

$$E = 6.45\ \text{keV} \qquad \sigma = 135\ \text{eV}$$

$$v = 2(2\ \ln 2)^{1/2} \sigma c E^{-1} \approx 1.5\times10^4\ \text{km s}^{-1}$$

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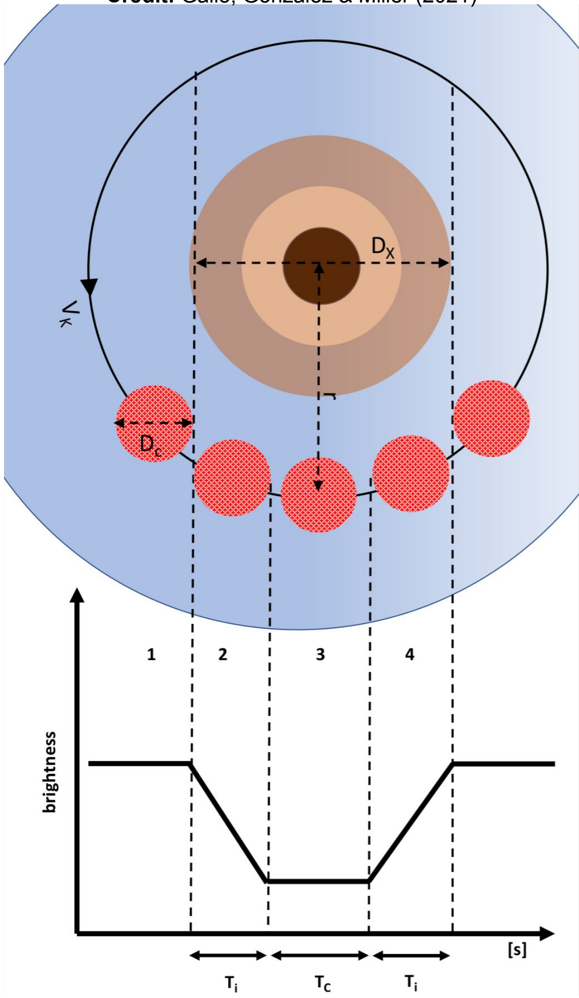
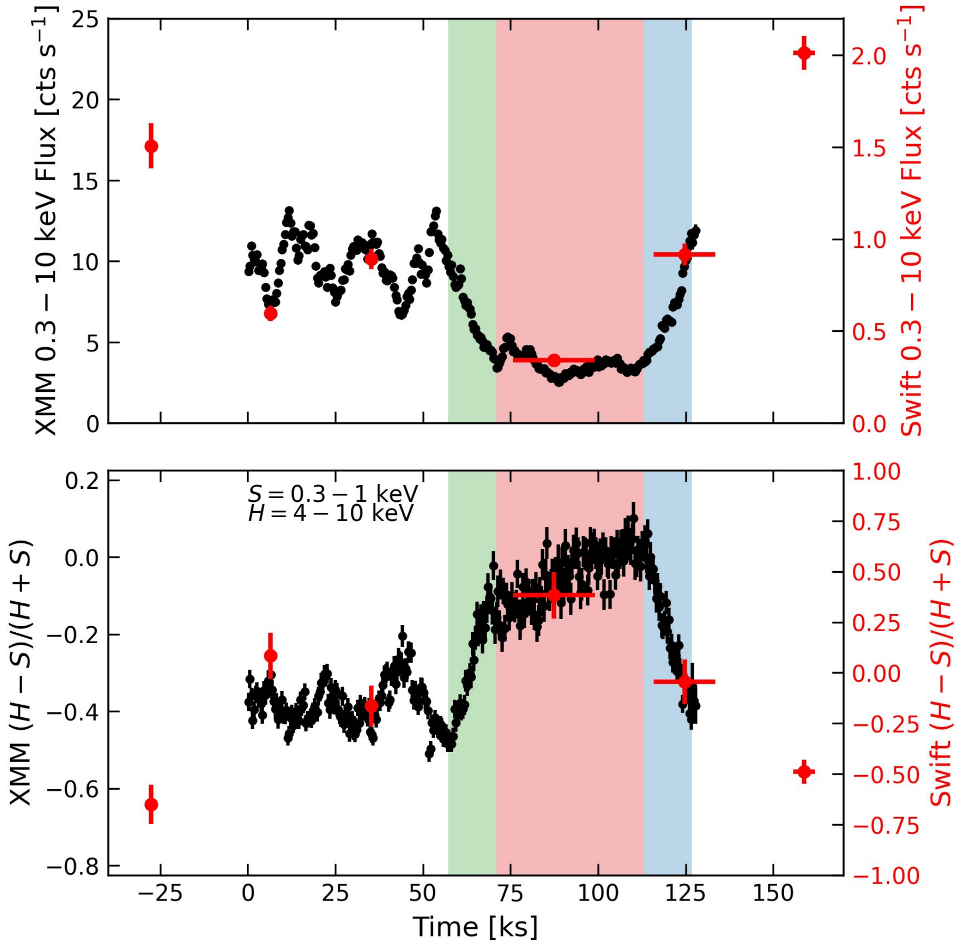


Swift 2022 Campaign

- *Swift* simultaneously observed during 2016 and caught the eclipse
  - Light curve and hardness ratio change in the same manner as *XMM* (high-soft to low-hard, and back again)



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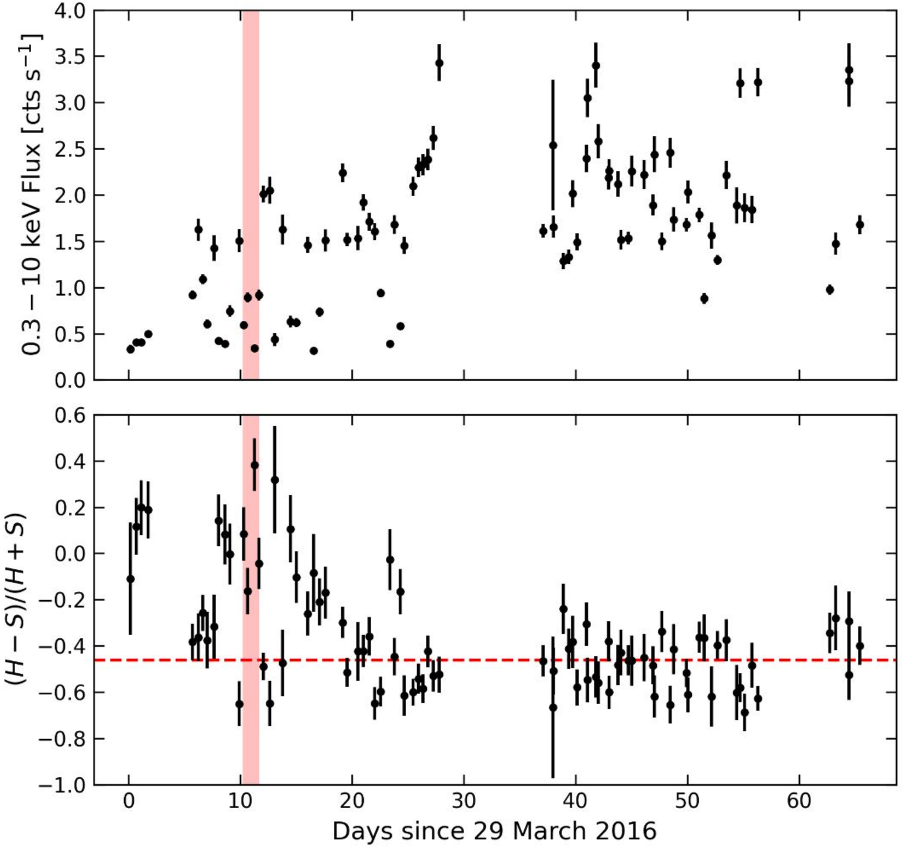

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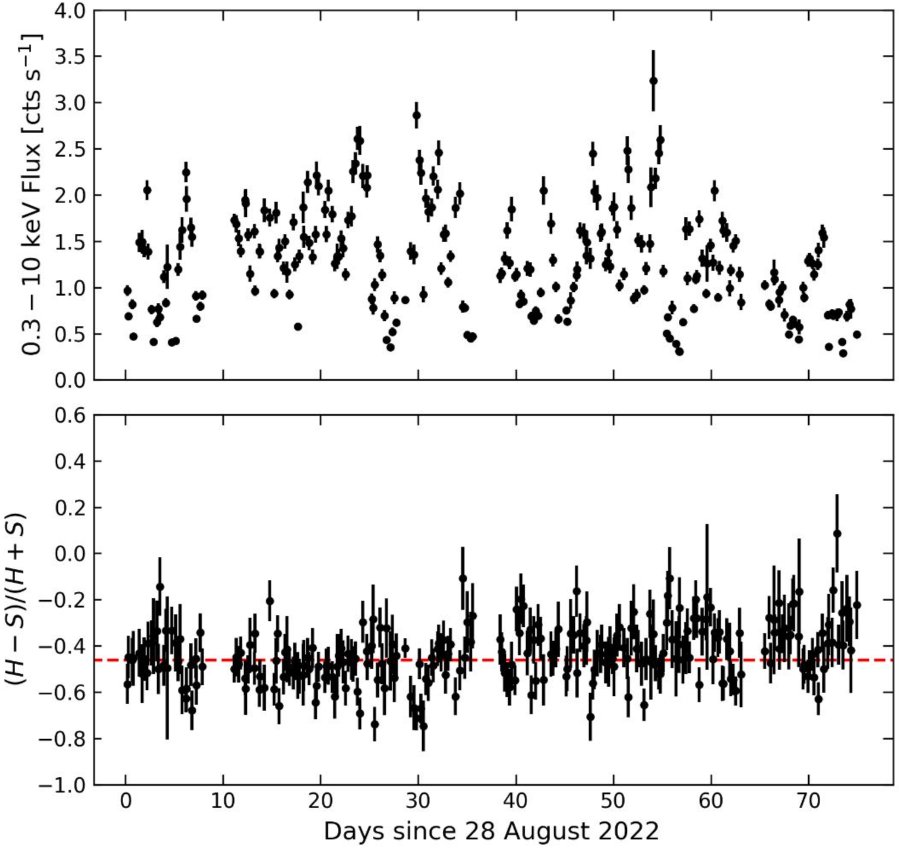
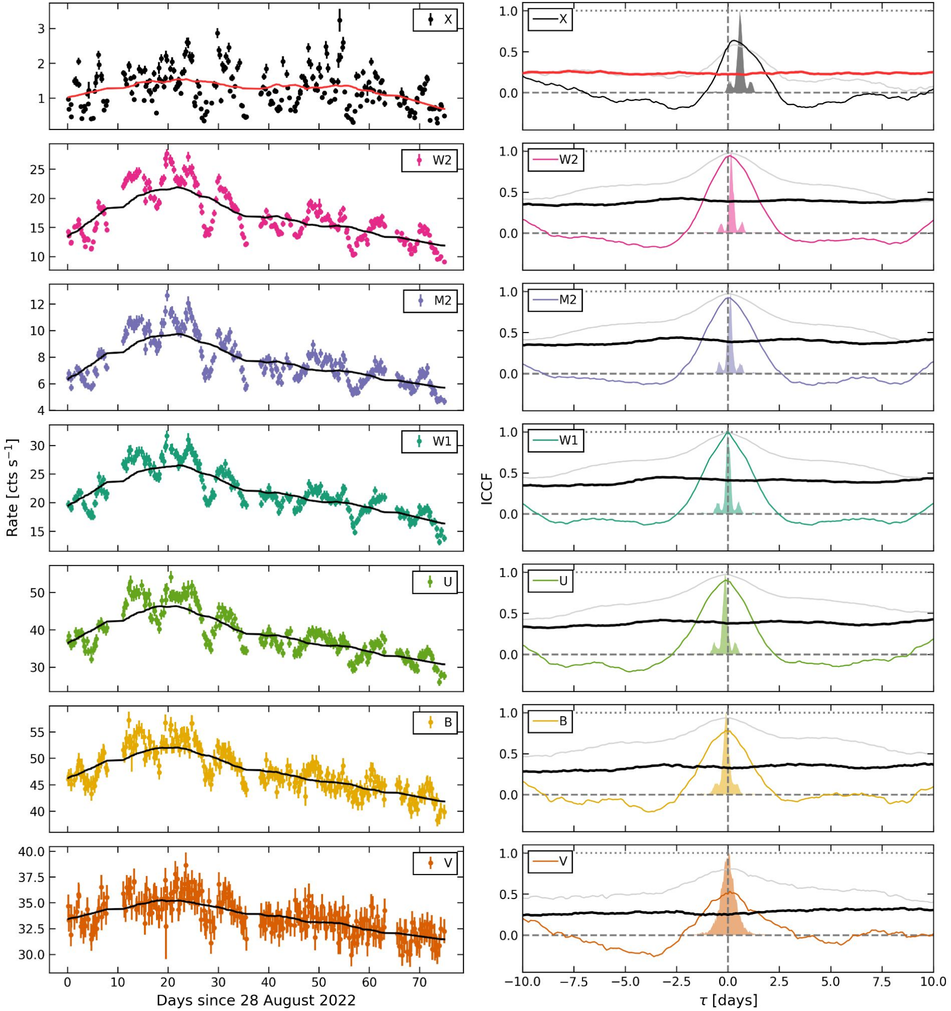


Swift 2022 Campaign

- Simultaneous multi-wavelength observations → map the disc
    - UV/optical data are strongly correlated
    - X-rays relationship is less clear
- Compute interpolated cross–correlation function w.r.t to *W1*
    - X-rays *lead* by 0.6 days
    - UV/optical data all exhibit much smaller lags relative to *W1*

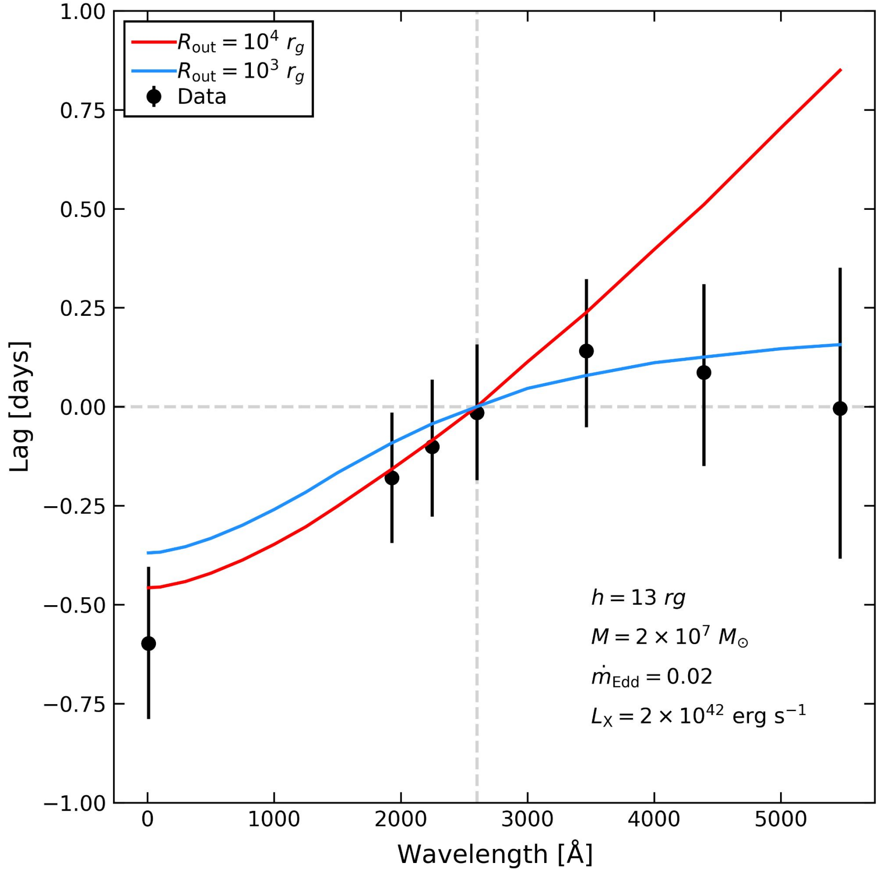


Swift 2022 Campaign

- Standard disc with $R_{\rm out} = 10^4\ r_g$ can explain X-ray and UV relation, but the optical rapidly flattens

- To explain the optical flattening, truncation to $R_{\rm out} \approx 10^3\ r_g$ is required

kynxilrev results



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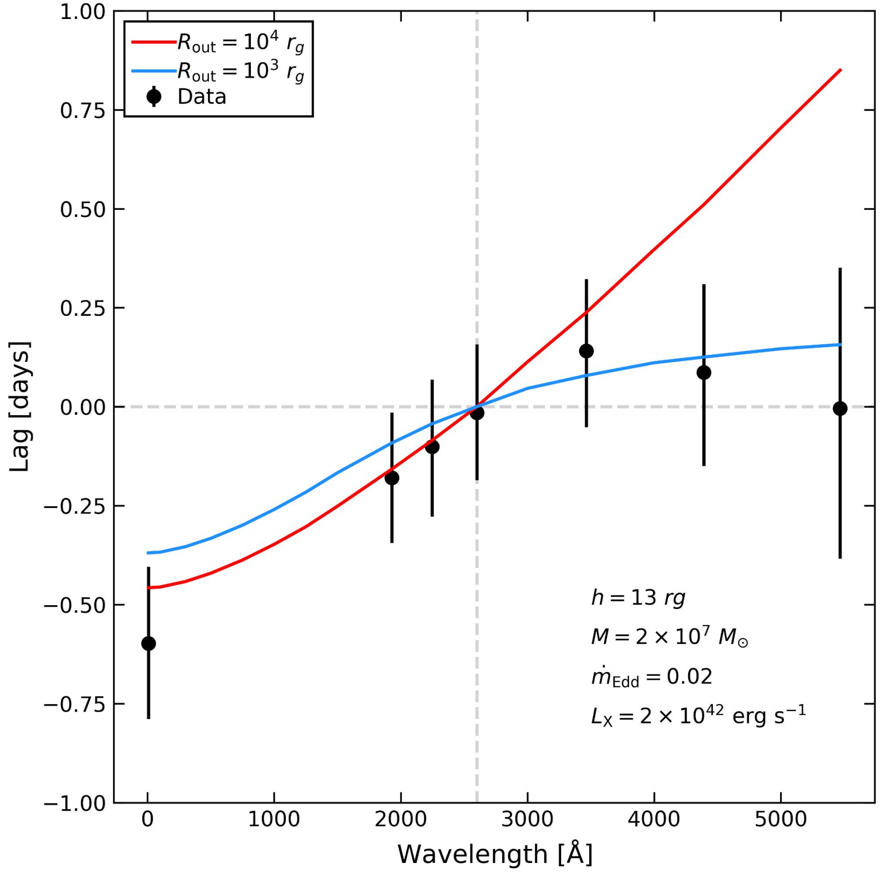
- Dust sublimation in the disc occurs when $T \approx 2000$ K, which is at least:

$$R_{min} \approx 0.018\ (L_{bol,46})^{1/2}\ \mathrm{pc} = 1145\ r_g$$

- The BLR may shield the disc at >$10^3\ r_g$, thus flattening the lags

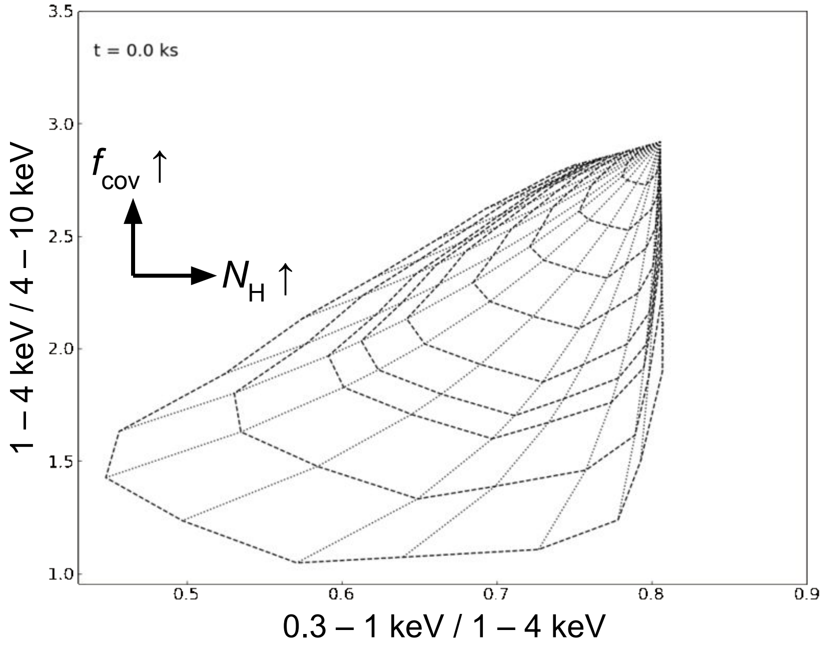
kynxilrev results

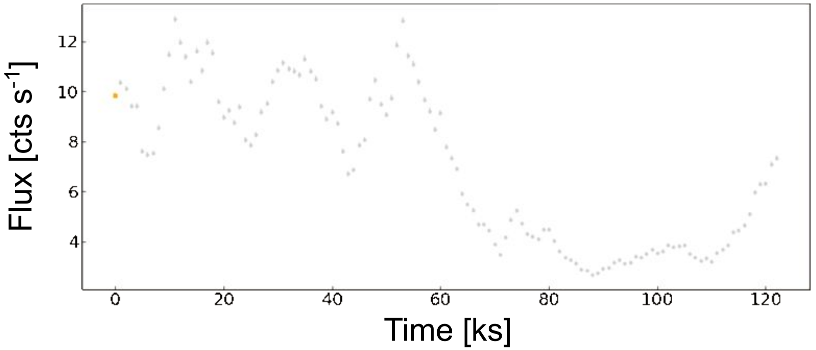


Ongoing Work

- Using the best-fit model from 2016 eclipse, predict the colour-colour space for varying N_H and f_{cov}

- Data ***do not*** follow the predictions of a single homogeneous cloud





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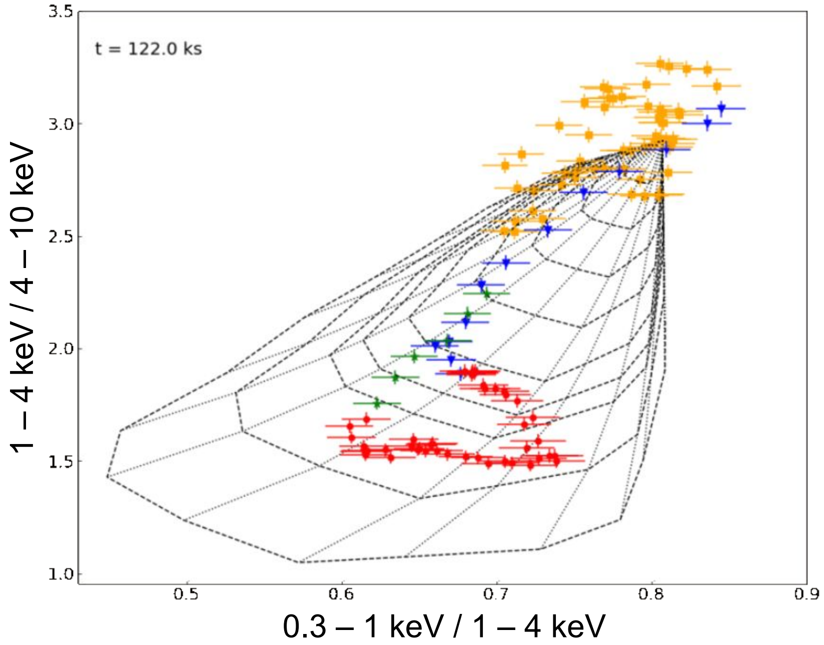

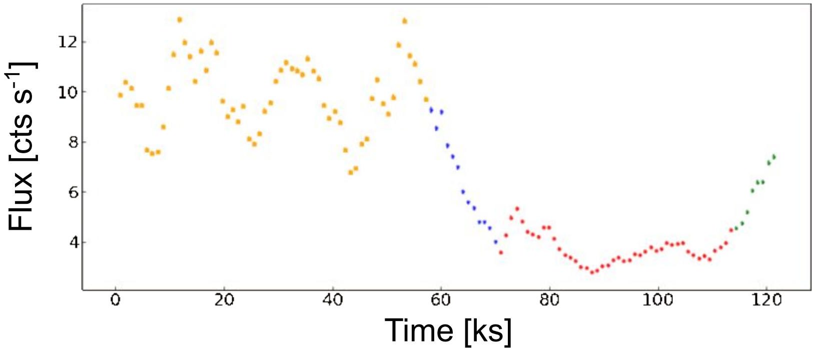

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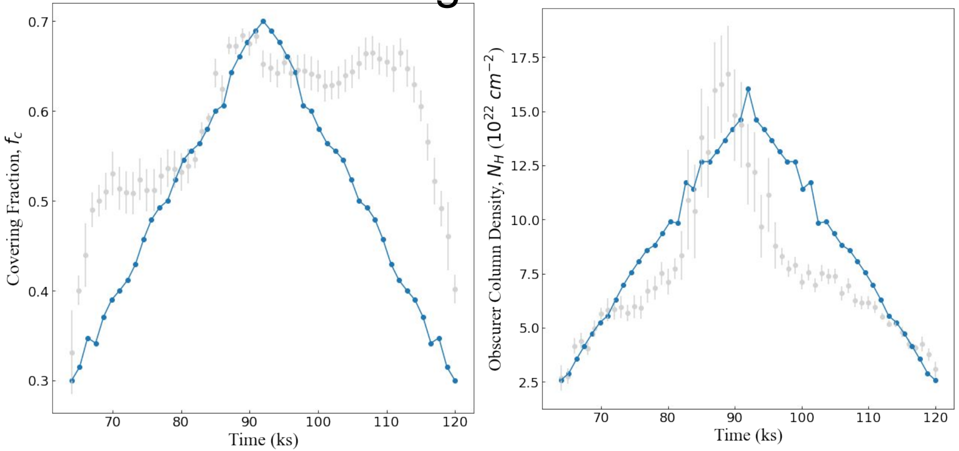
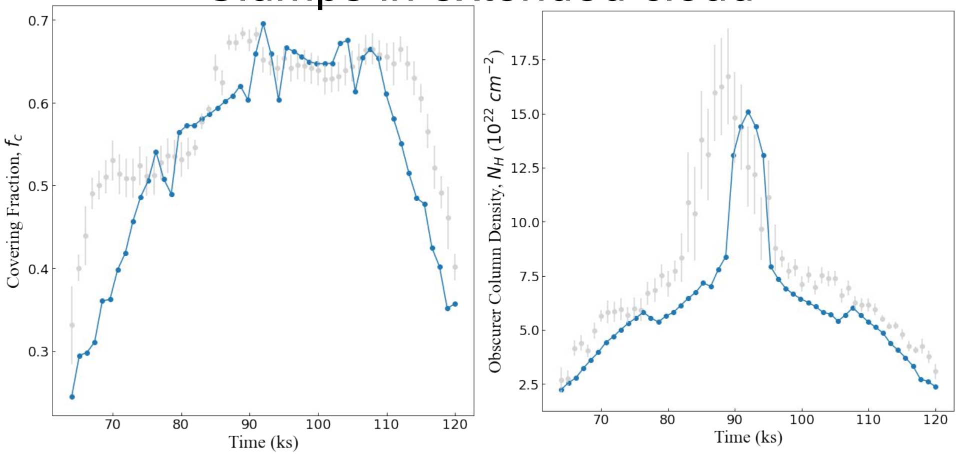
- Using the best-fit model from 2016 eclipse, predict the colour-colour space for varying N_H and f_{cov}
- Data ***do not*** follow the predictions of a single homogeneous cloud
- Suggests an inhomogeneous, clumps embedded within extended large-scale structure
- Are we probing different regions of the BLR? Or the cloud geometry / structure? A clumpy wind / outflow?

One homogeneous cloud



Clumps in extended cloud

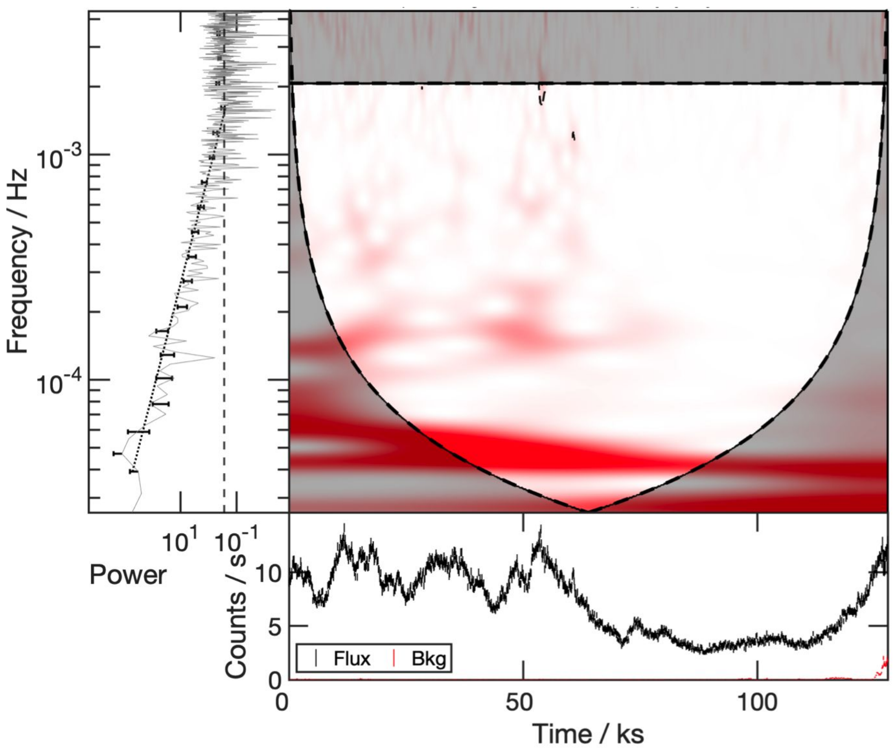


Ongoing Work

- Pre-eclipse data offer tantalizing 'hints' toward a periodic process in this source on ~20 ks time-scales

- Using wavelet analysis to examine ***both*** the frequency- and time-dependence of the signal simultaneously reveals a persistent signal that modulates in frequency

- The frequency changes when the eclipse starts → absorption-induced phase-modulation?



Summary & Conclusions

- The rapid obscuration event in 2016 may be due to BLR material in our line-of-sight to central engine
- The reduced optical lags observed in 2022 may be BLR formation at ~10^3 r_g which shields outer disc
- Still much to learn & understand …

Thank you!

<u>X-ray eclipse in NGC 6814</u>
Gallo, Gonzalez & Miller (2021)

<u>Absorber inhomogeneity in NGC 6814</u>
Pottie, Gallo, Gonzalez & Miller (submitted)

<u>Wavelets analysis of AGNs</u>
Ghosh, Gallo & Gonzalez (submitted)

<u>*Swift* 2022 campaign of NGC 6814</u>
Gonzalez, Gallo, Pottie, Miller & Kammoun (in prep.)