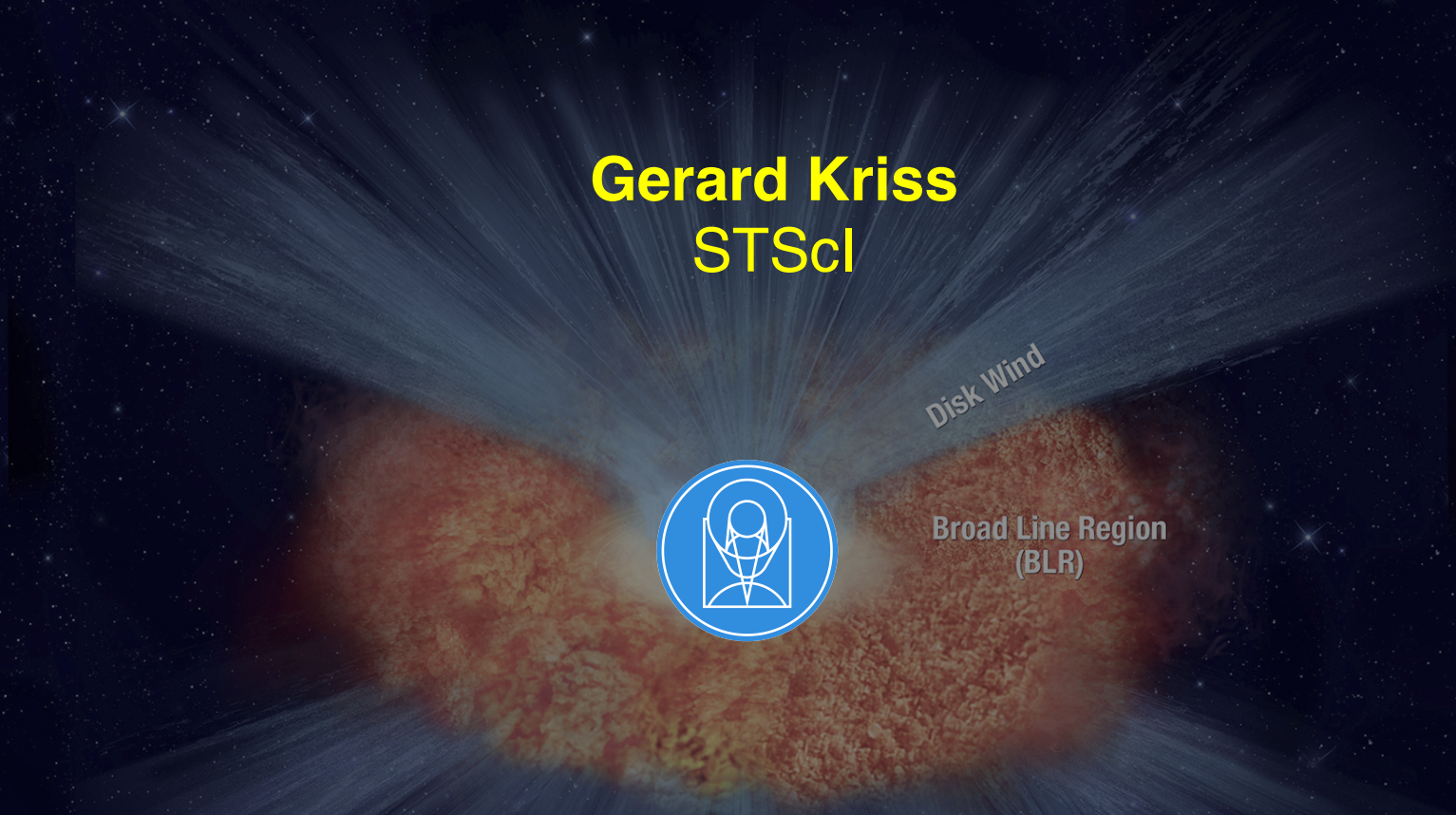
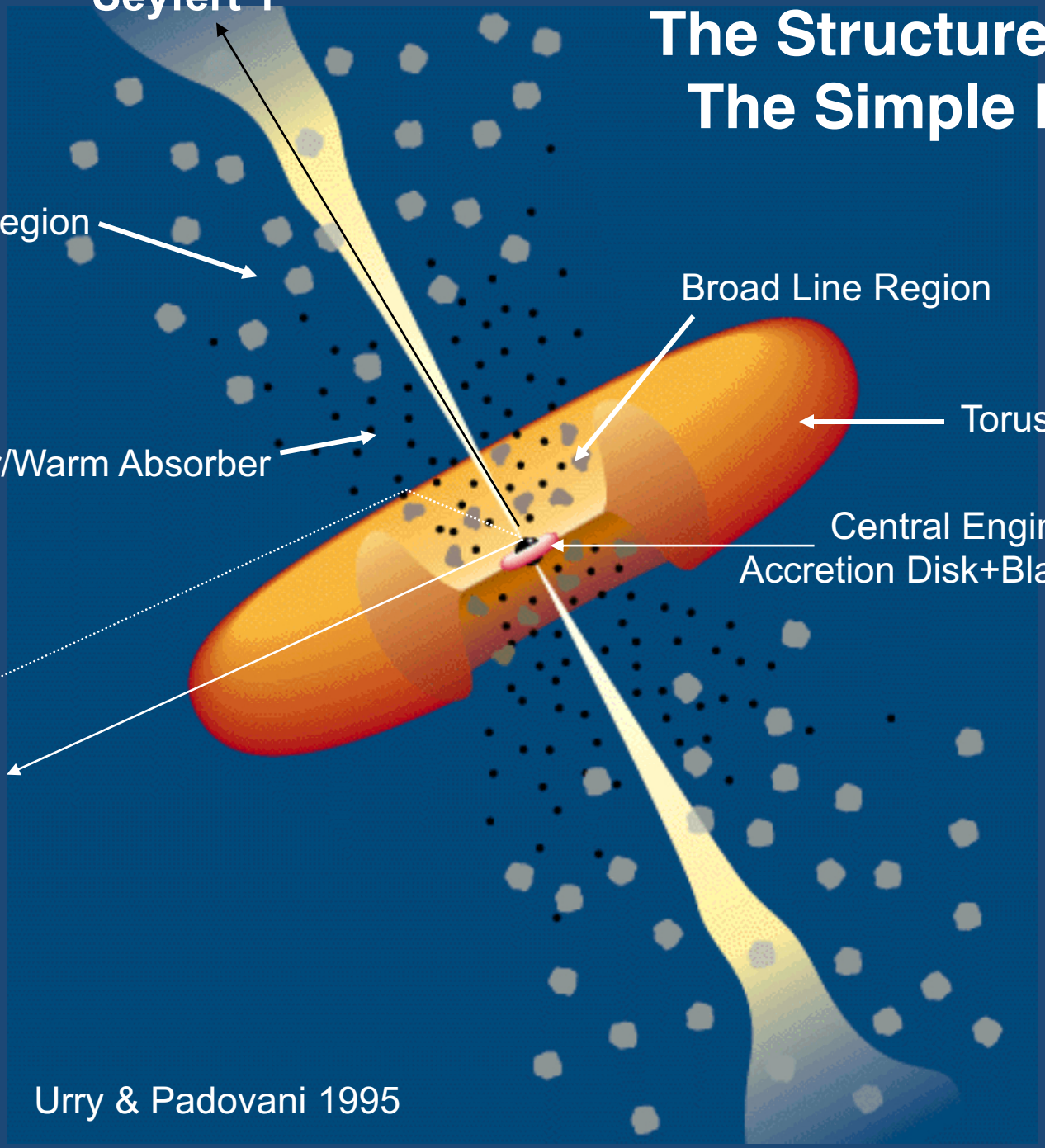
X-ray and UV Monitoring Campaigns Reveal the Structure and Dynamics of AGN Outflows

Gerard Kriss
STScI



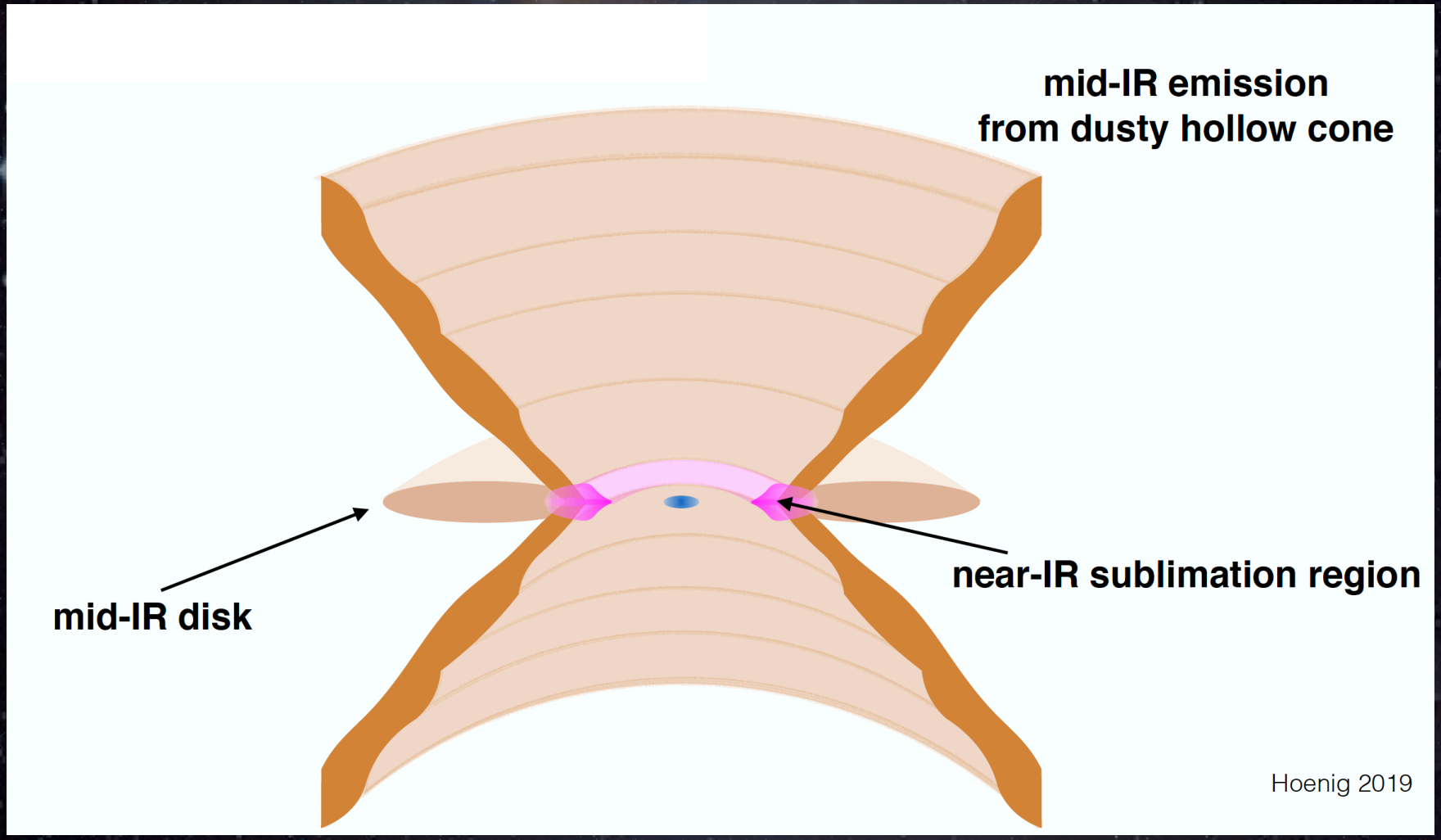
Collaborators:
Brad Peterson, Gisella de Rosa, Jelle Kaastra, Missagh Mehdipour, Maryam Dehghanian, Gary Ferland & the NGC 5548 and NGC 3783 Teams

The Structure of AGN
The Simple Picture

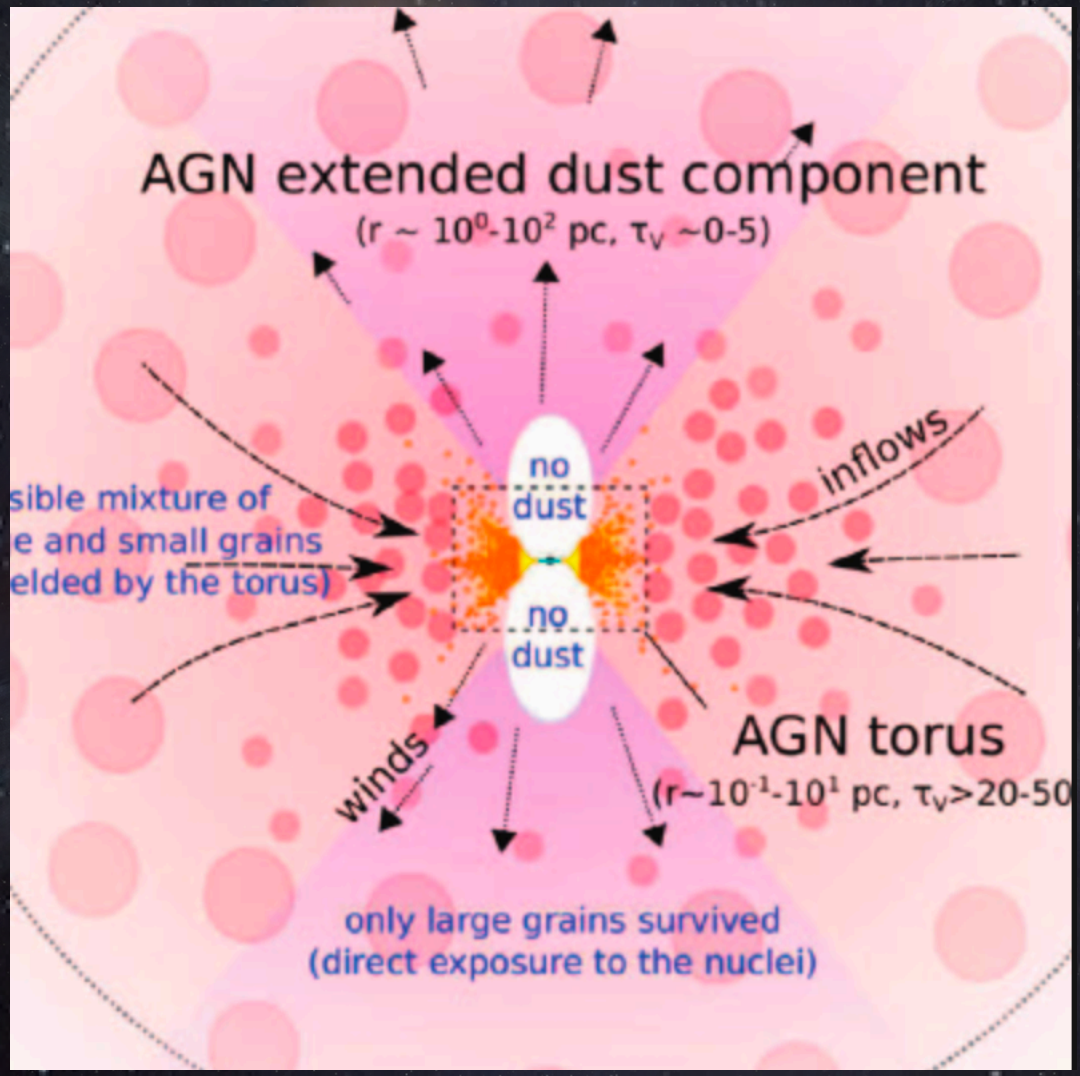


Urry & Padovani 1995

The Structure of AGN—The Not so Simple Picture

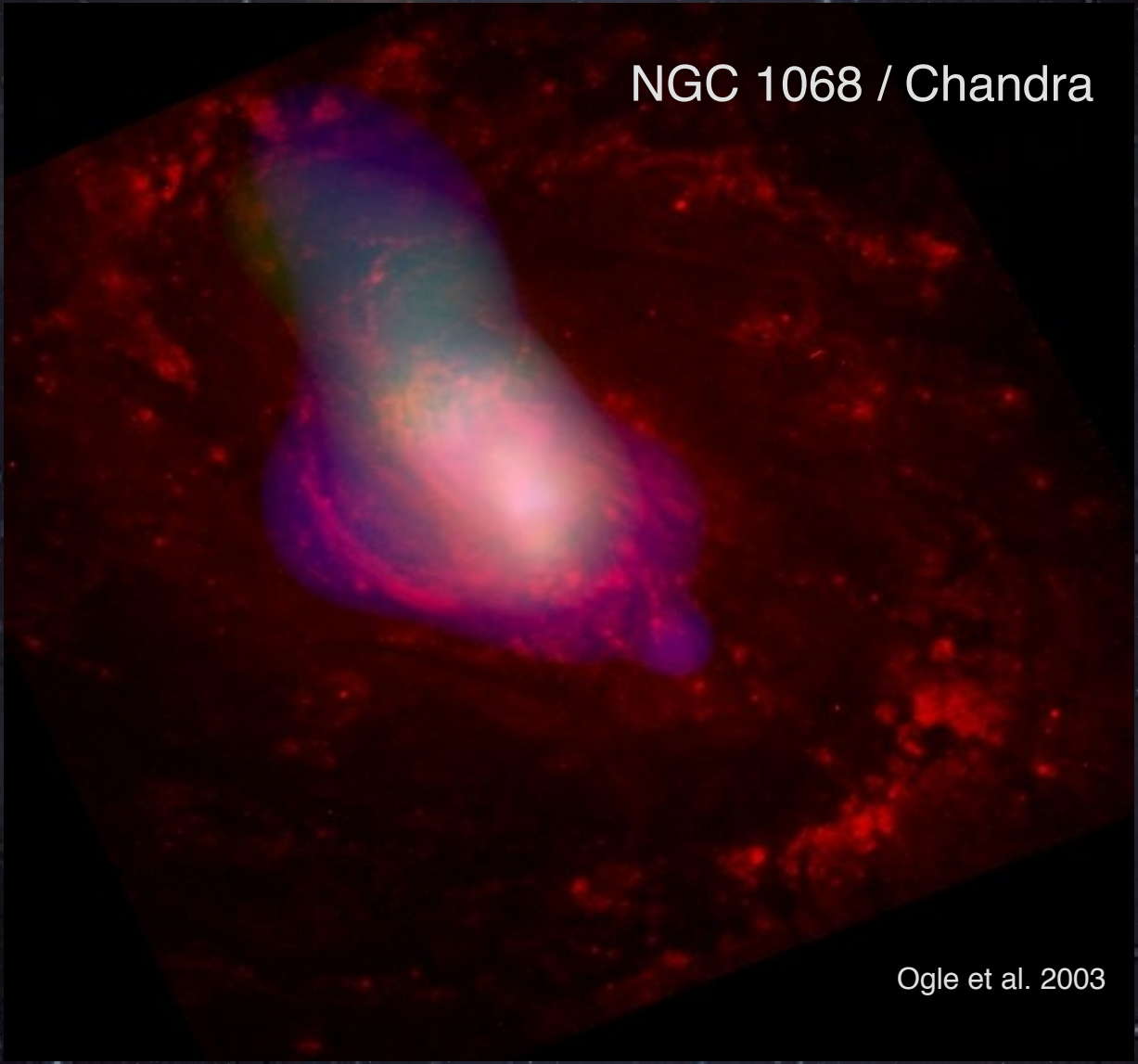


The Structure of AGN—The Not so Simple Picture

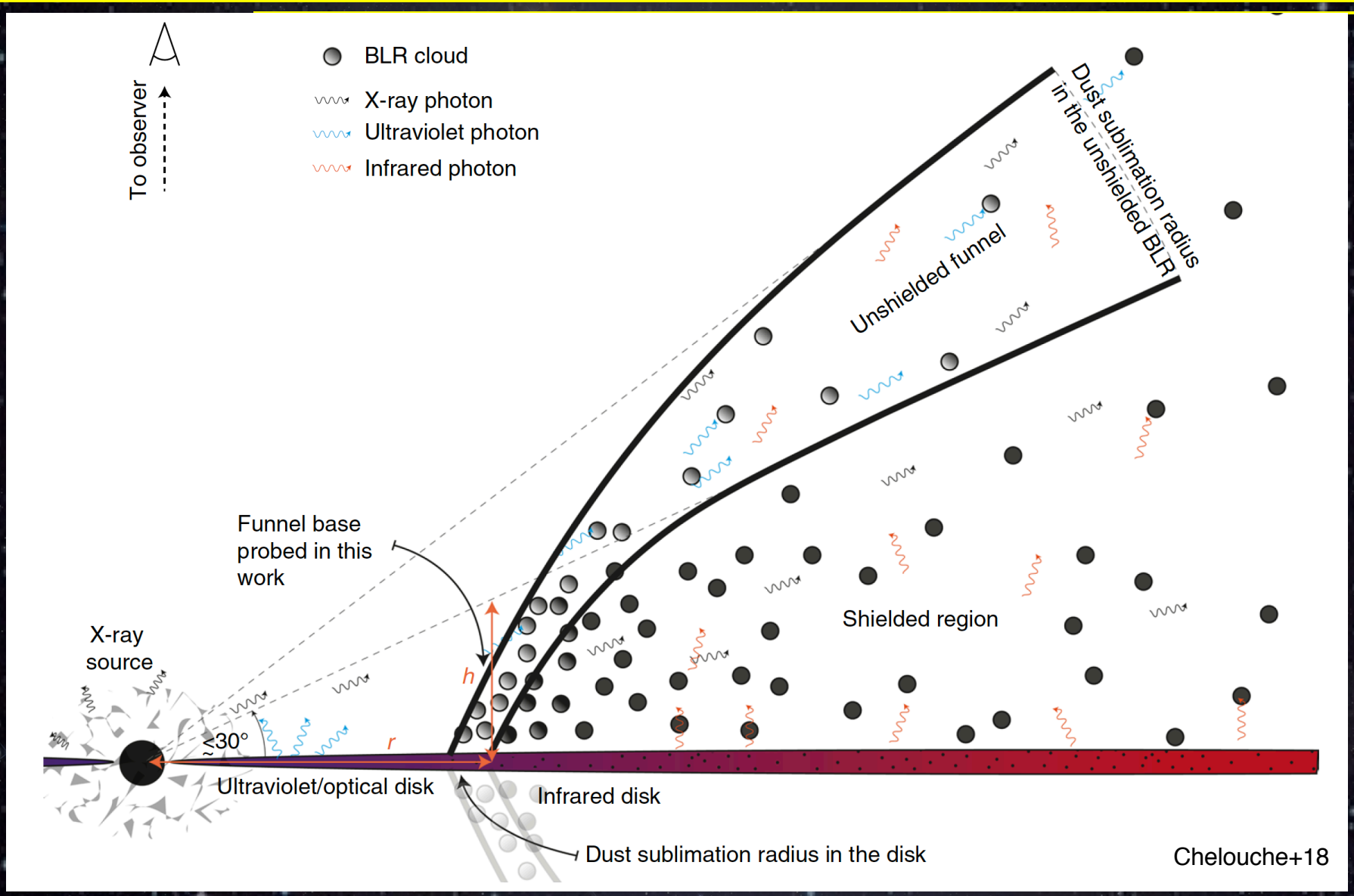


Lyu & Rieke 2018

X-ray Outflows in Nearby AGN are Extended



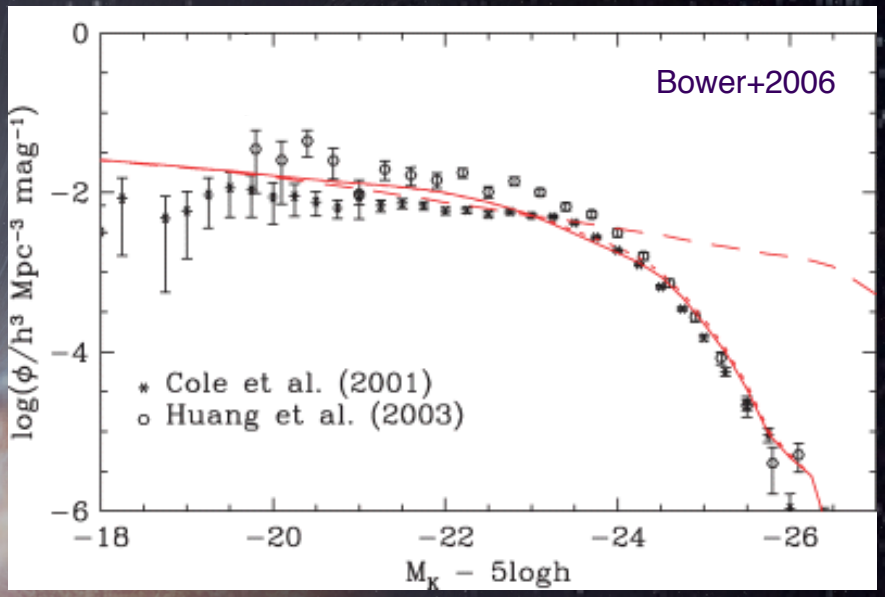
The Structure Close to the Black Hole is Driven by Outflows



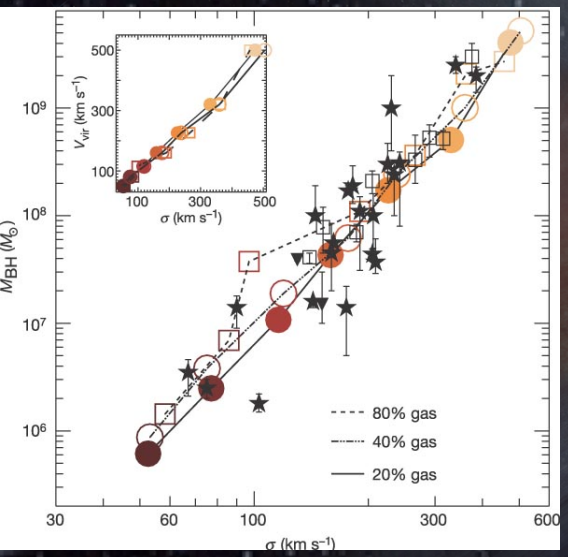
Chelouche+18

The Influence of AGN Outflows

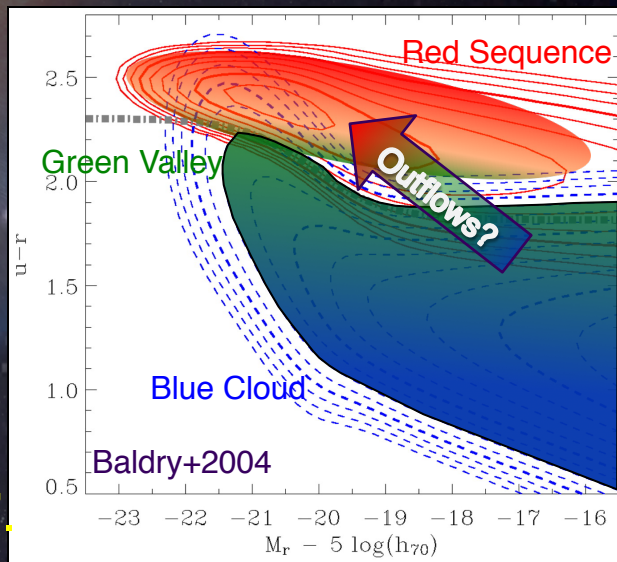
- ★ Downsizing: AGN feedback limits galaxy growth.



DiMatteo+2005



- ★ M_{BH}-σ : Feedback couples black hole growth to galaxy growth, leading to the correlation.



- ★ Color Evolution: Outflows can help AGN move from the “Blue Cloud” across the “Green Valley” and onto the “Red Sequence”.

What would constitute a significant outflow?

We need sufficient mass flux and velocity so that

$$L_k = \frac{1}{2} \dot{M}_{out} v_{out}^2 \quad > \quad 0.5\text{-}5\%\ L_{rad} = 0.5\text{-}5\%\ \eta\ \dot{M}_{acc} c^2$$

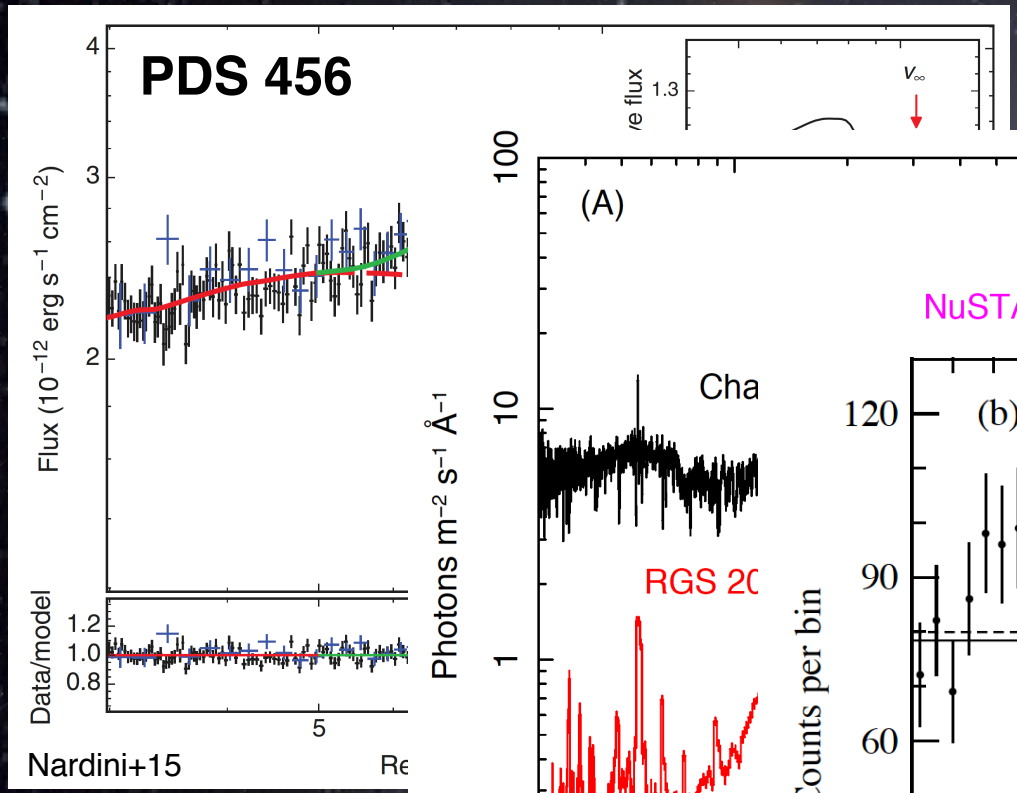
If $\dot{M}_{out} \sim \dot{M}_{acc}$, then

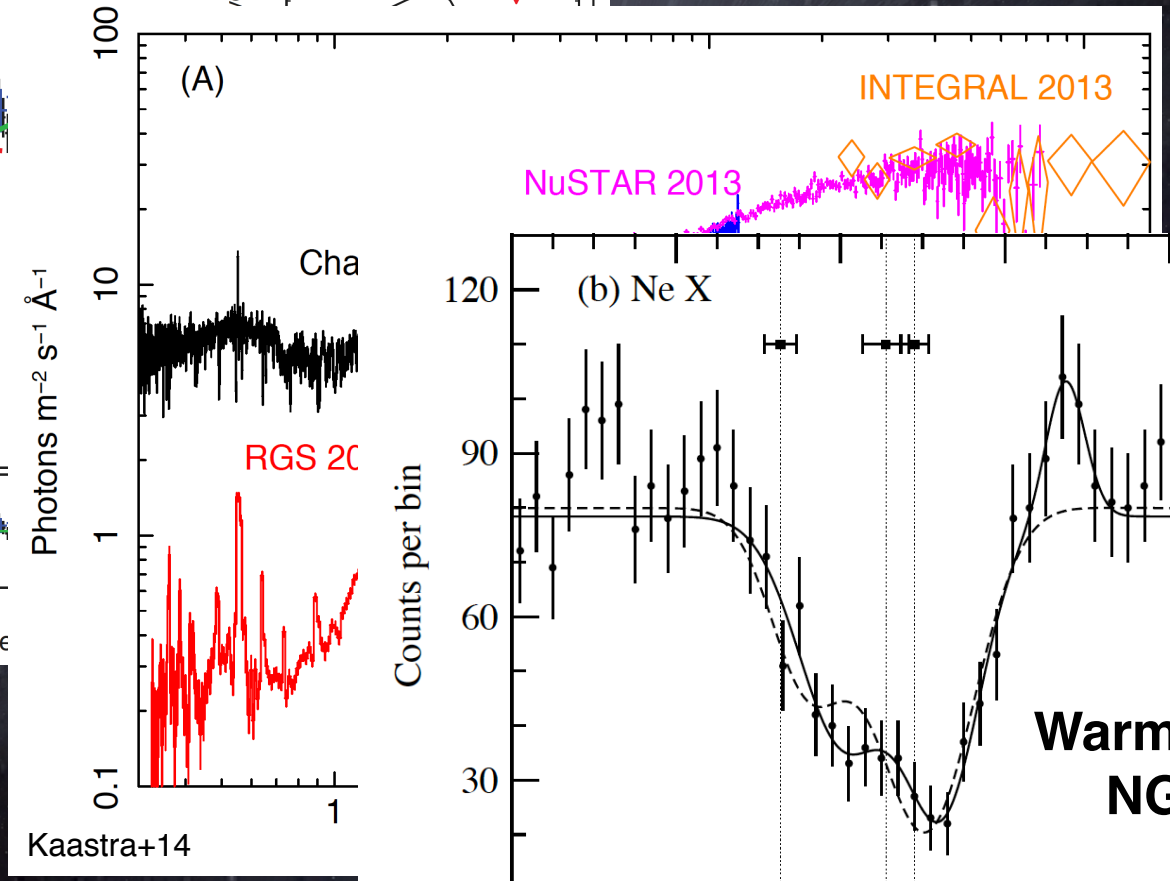
$$v_{out}^2 > 2 \times (0.5\text{-}5\%)\ \eta\ c^2$$

Since $\eta \sim 0.1$,

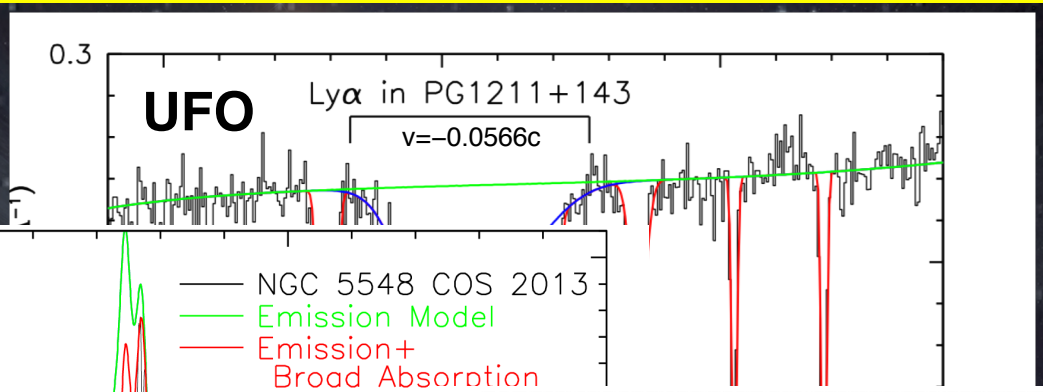
$$v_{out} > 0.01\text{—}0.1\ c$$

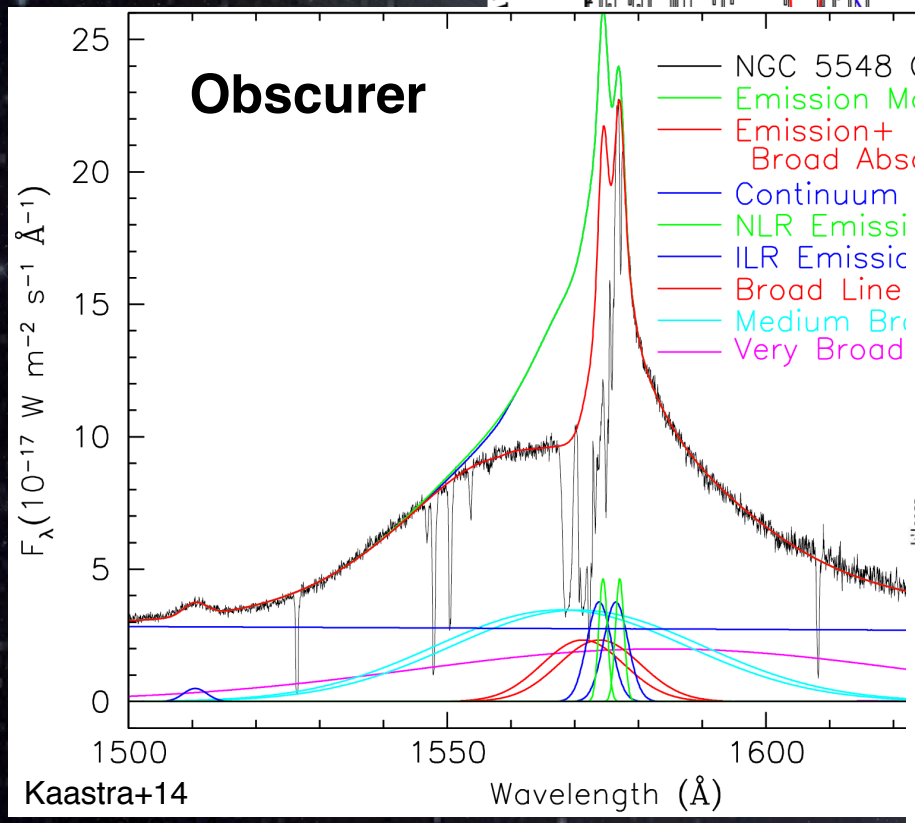
X-ray Outflows in AGN Span a Wide Range in Velocity



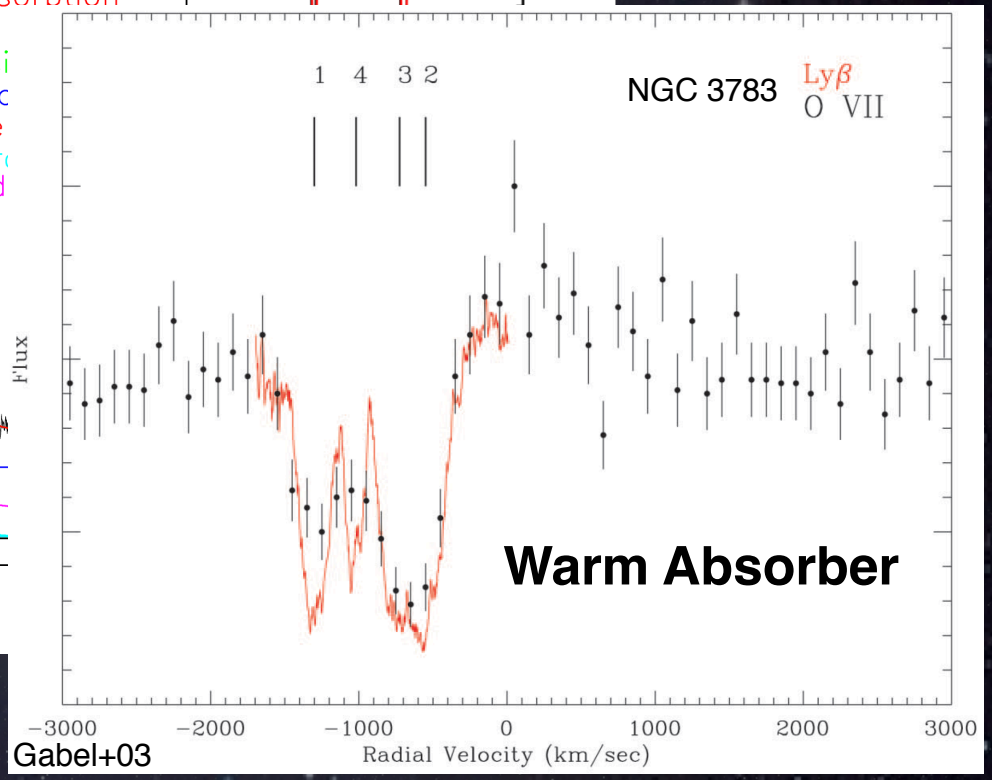


All X-ray Outflows Have an Ultraviolet "Footprint"



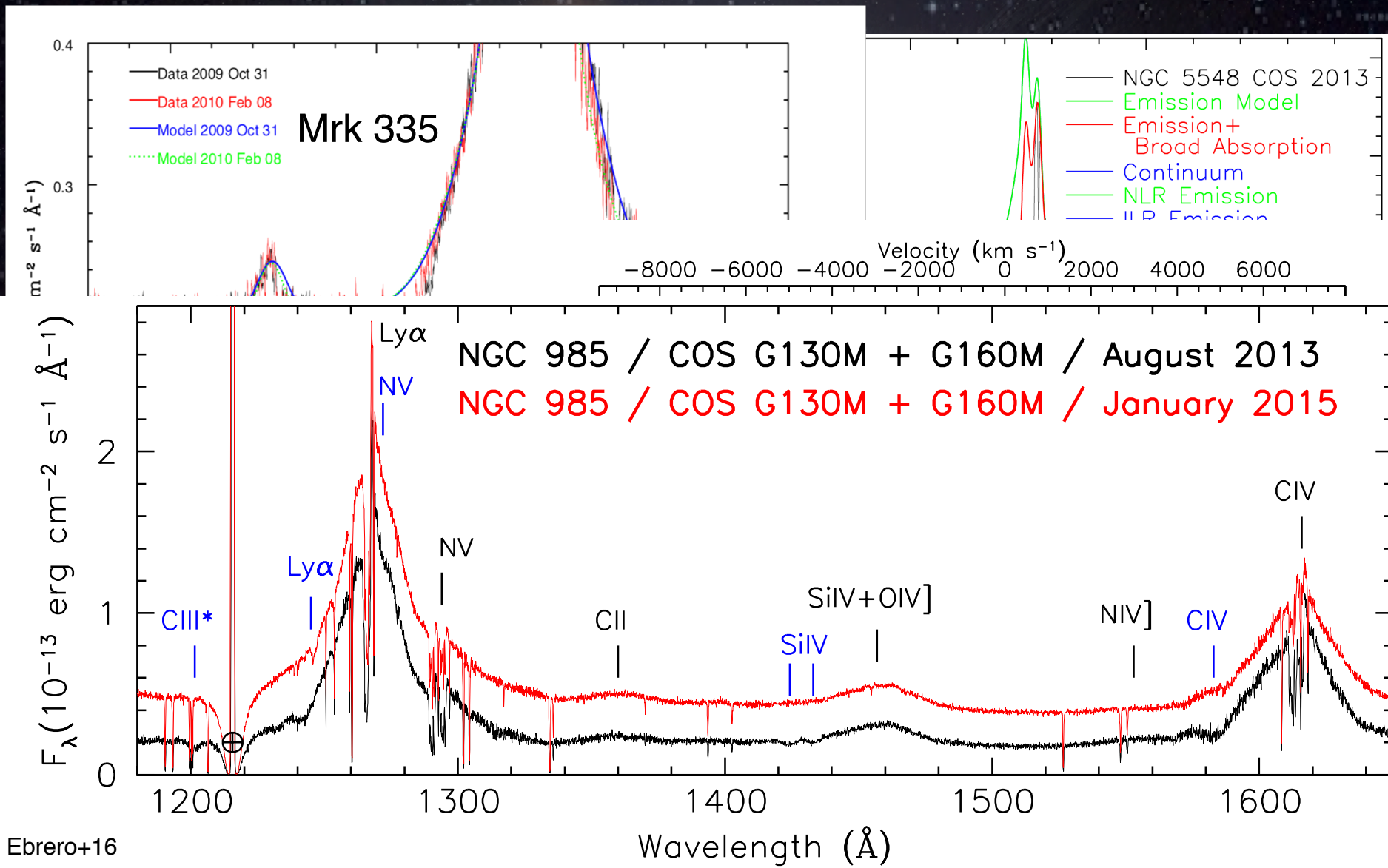


Kaastra+14



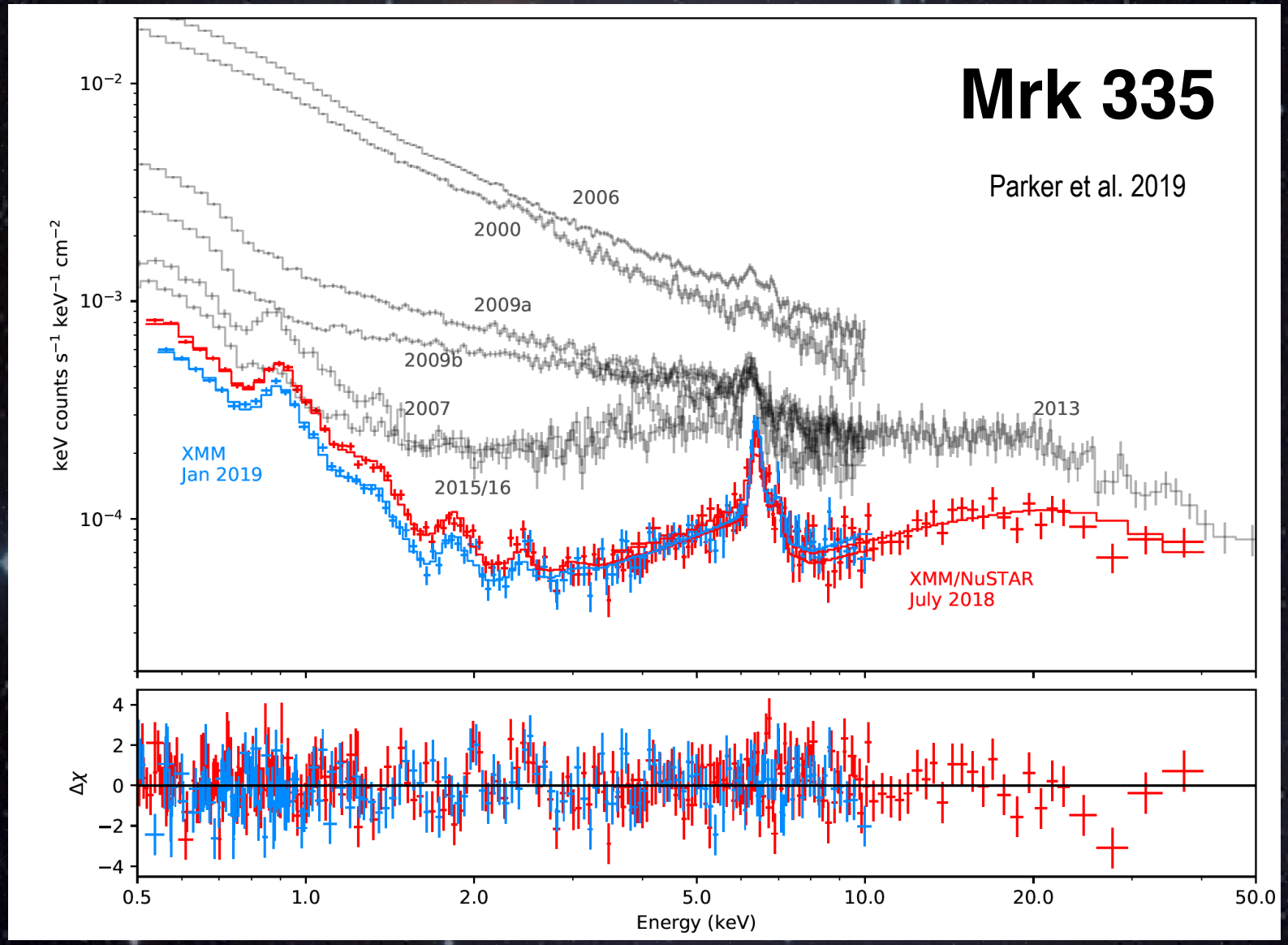
Gabel+03

Four Recently Discovered Cases of X-ray+UV Obscuration

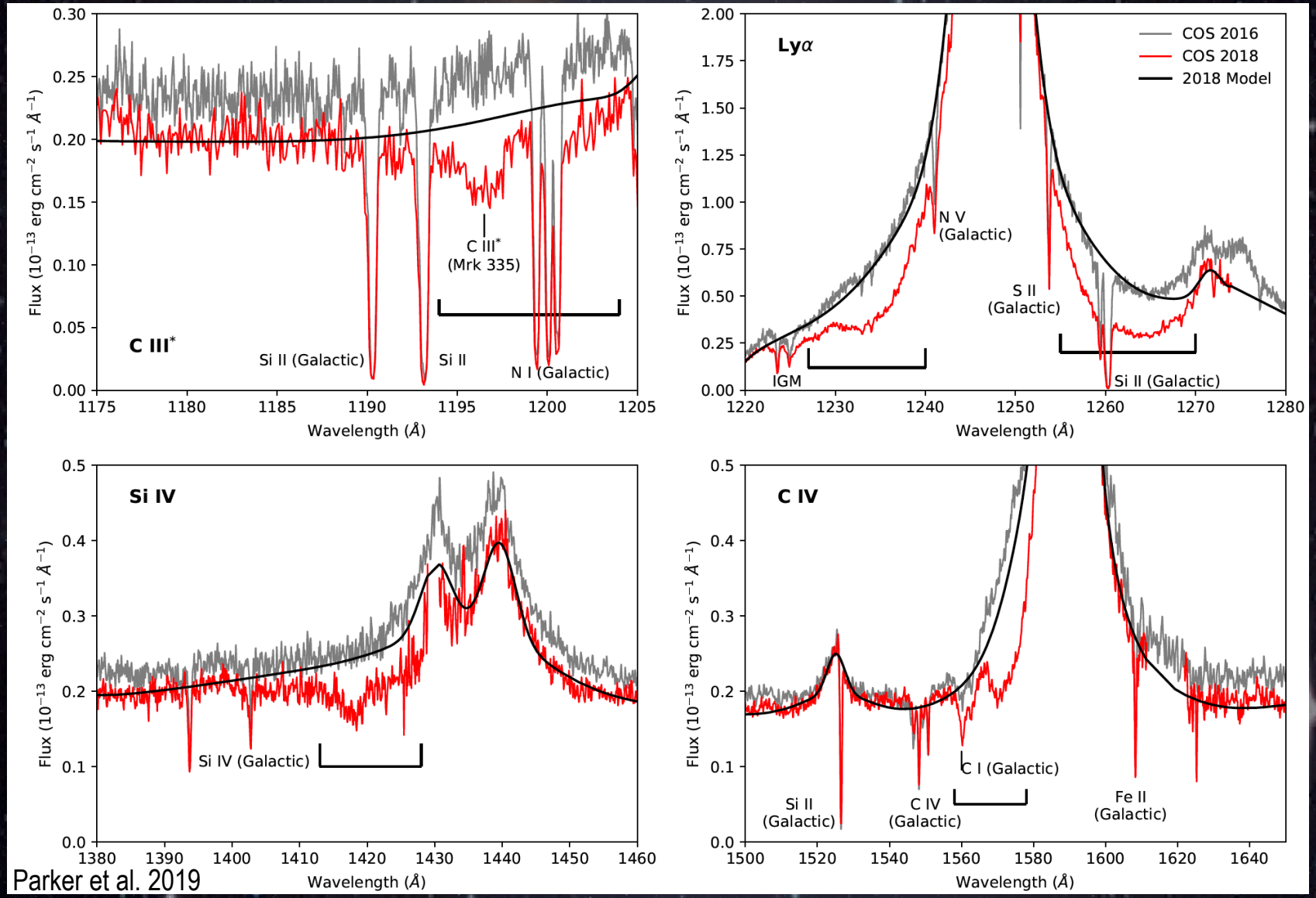


Ebrero+16

Evolution in X-ray Spectra of Mrk 335



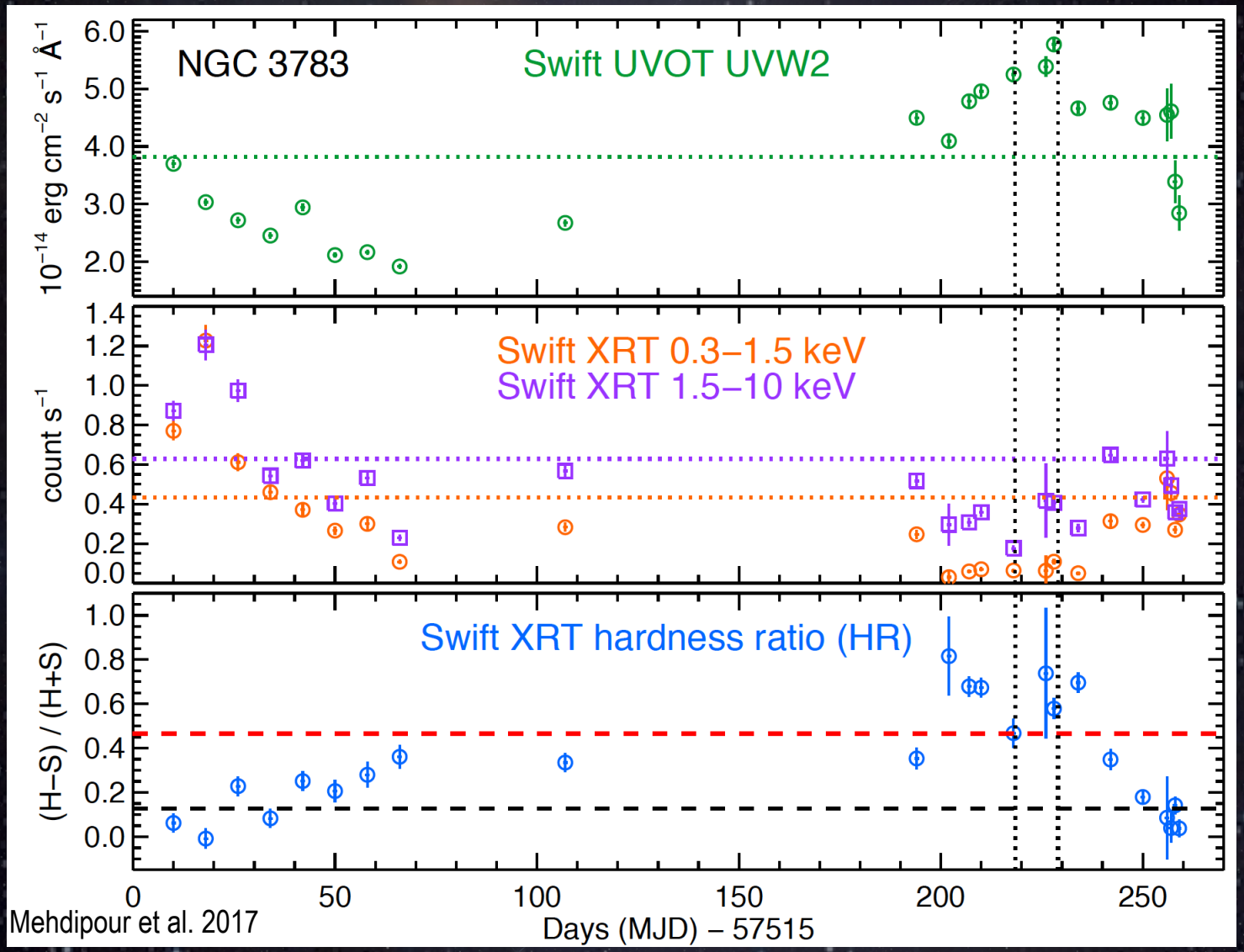
Deepening UV Absorption in Mrk 335



Parker et al. 2019

Obscuration Event in NGC 3783 in December 2016

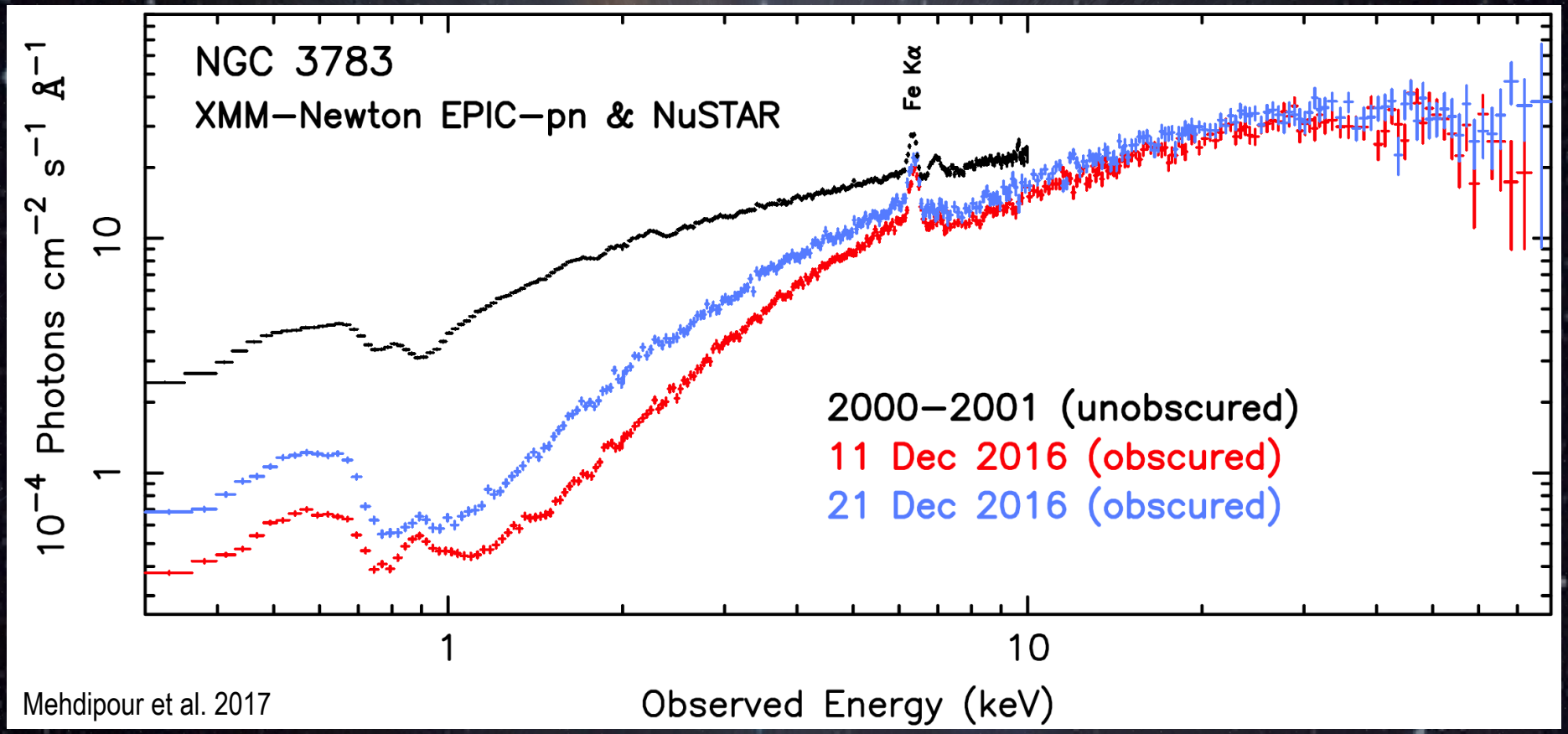
Swift Trigger on Hardness Ratio



Mehdipour et al. 2017

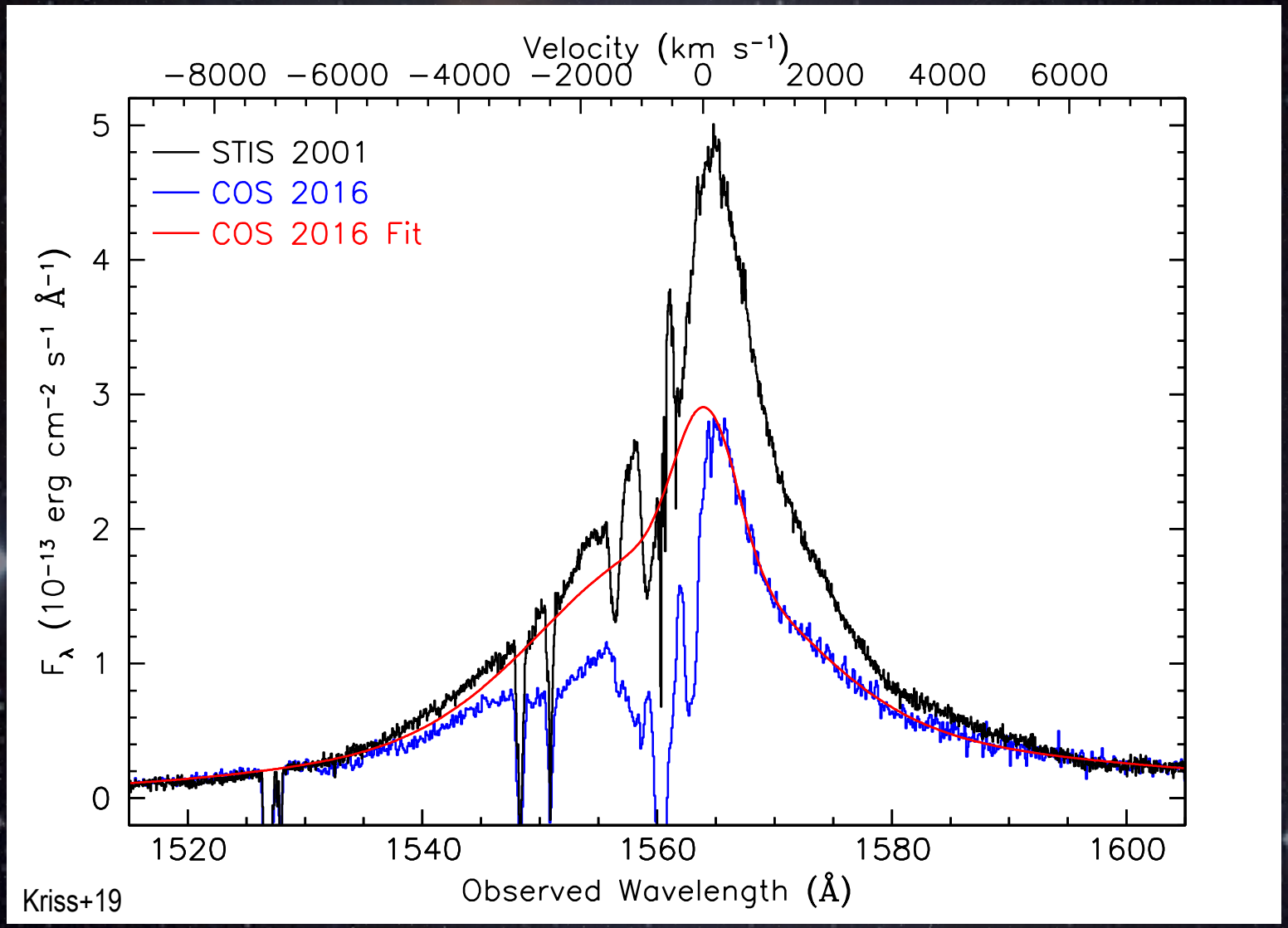
Obscuration Event in NGC 3783 in December 2016

XMM-Newton pn + NuSTAR Spectra



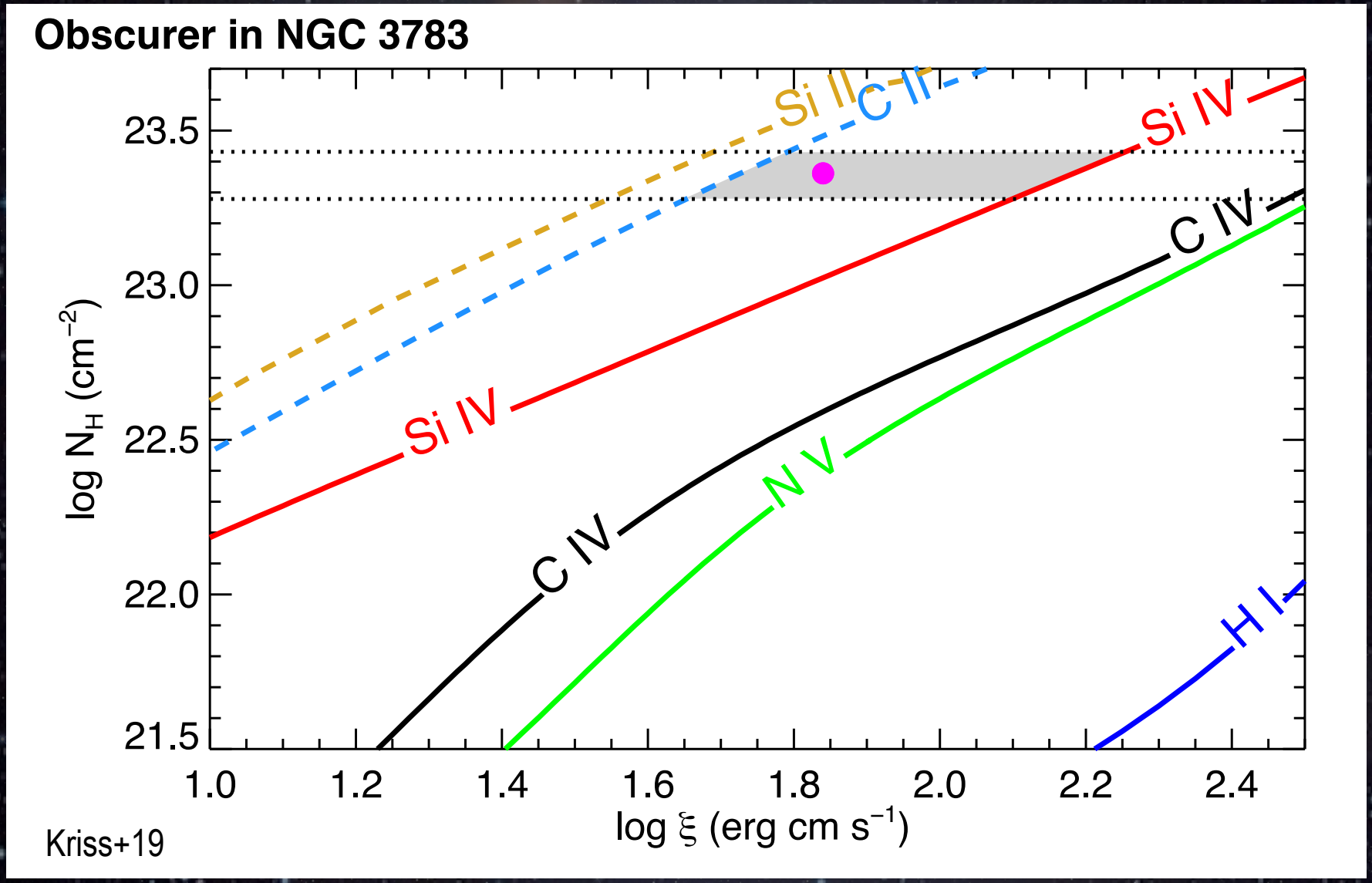
Mehdipour et al. 2017

Broad UV Absorption Accompanied the X-ray Obscuration in NGC 3783

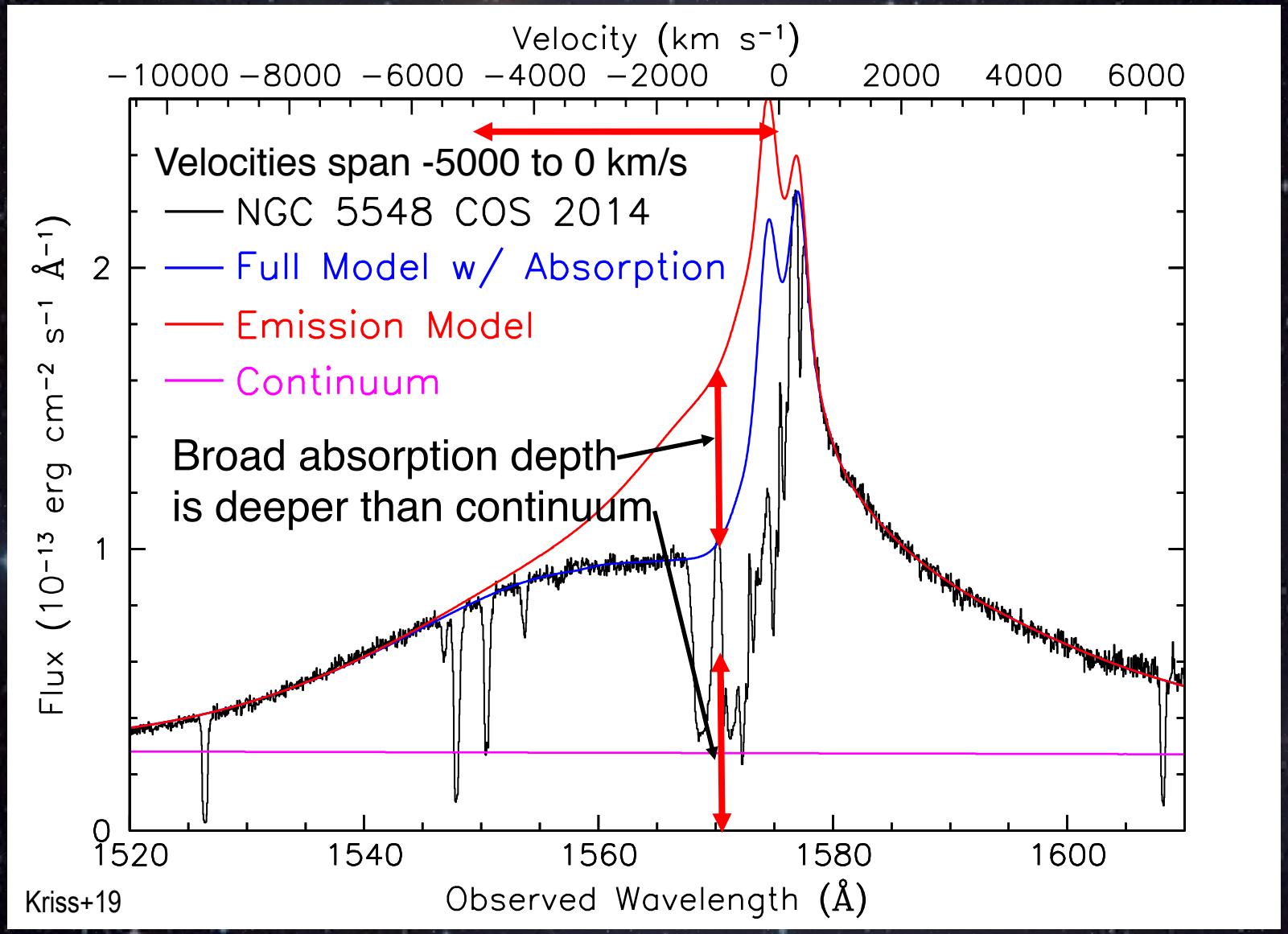


X-ray+UV are Needed to Measure Physical Conditions

X-ray -> Total Column Density, UV -> Ionization Parameter



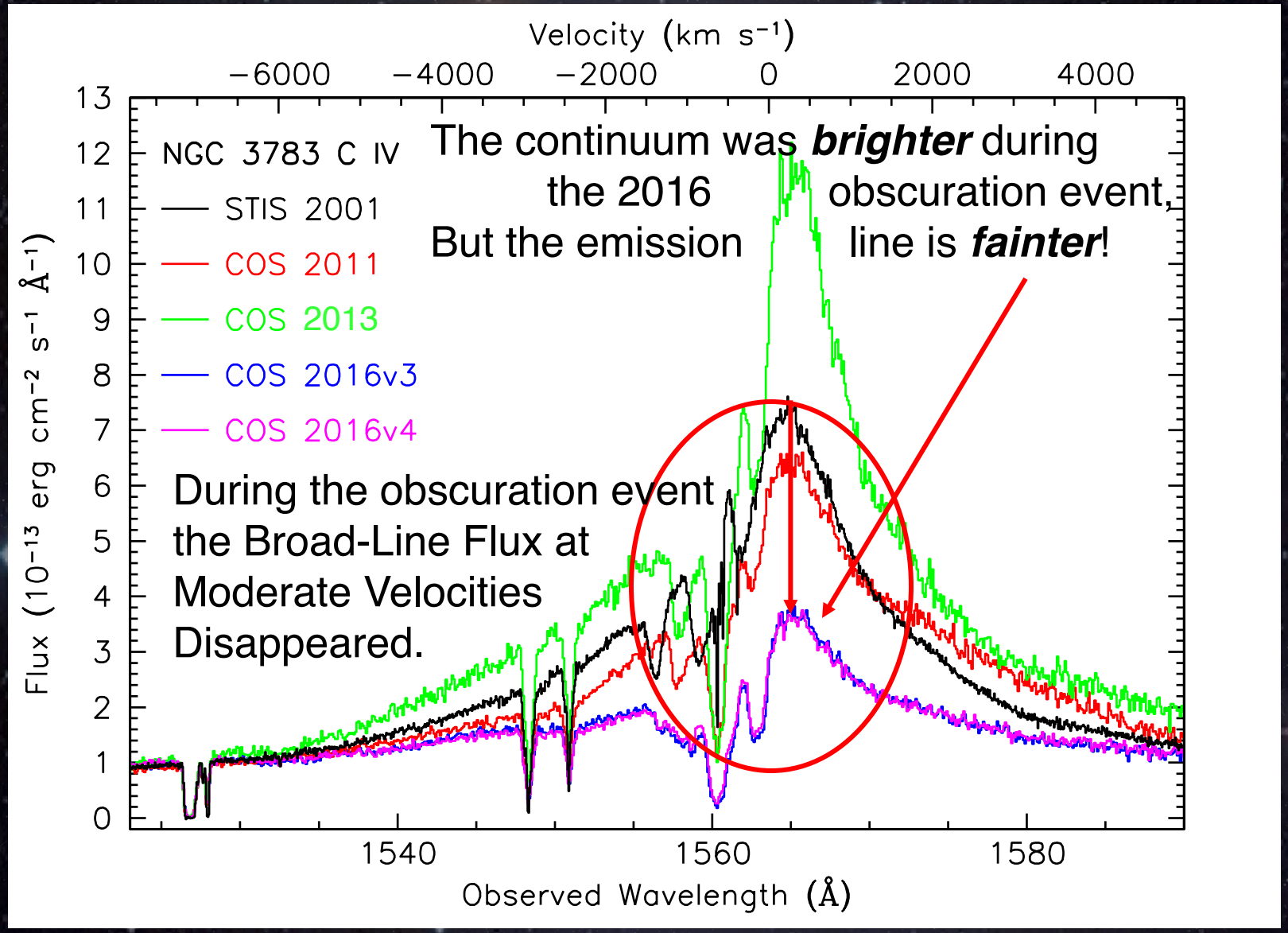
UV Also Provides Kinematics and Location (via Covering factors)



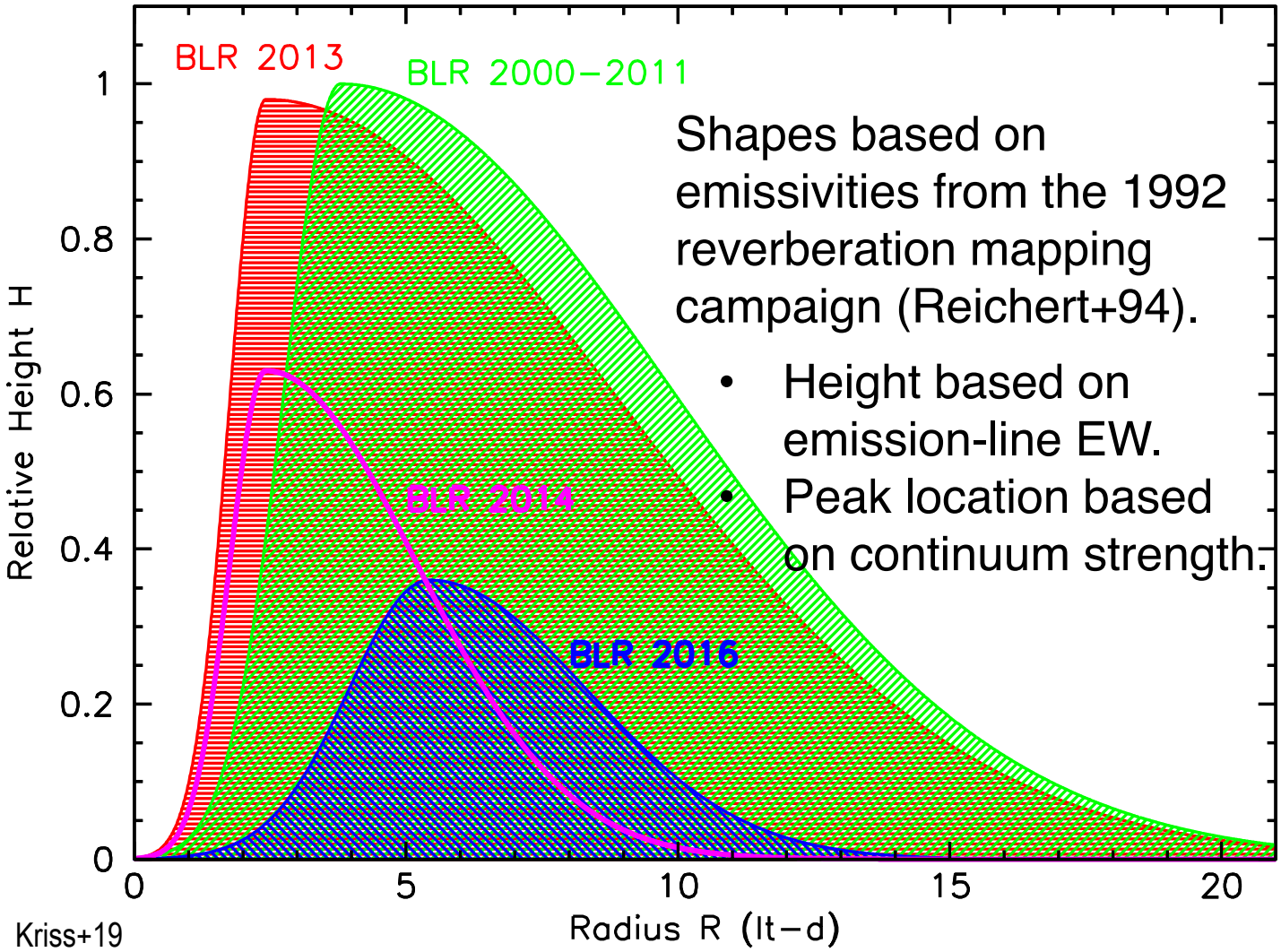
Where do obscuring outflows originate?

- **Velocities are typical of AGN broad line regions, viz., the absorption in NGC 5548 and NGC 3783 covers nearly the whole blue wing of the C IV absorption line.**
- **The obscuration is interior to the narrow-line absorbers (which are co-spatial with the NLR) in NGC 5548 and NGC 3783.**
- **X-ray absorption in NGC 5548 is variable on timescales of < 1 day.**
  - If an ionization response, it is rapid enough that the density must be of order 10^9 cm^{-3} again, typical of the broad-line region.
  - Given this density and the ionization parameter, it is located at ~10^{15} cm, again, near the inner edge of the broad-line region/outer edge of the accretion disk.
- **X-ray obscuration in NGC 3783 lasts ~1 month.**
  - The obscurer partially covers the X-ray source, making it comparable in size, ~10^{13} cm.
  - Crossing time of 30 days gives a velocity of 320 km s^{-1}, placing it at a distance of ~10^{15} cm.

Evolution in the Equivalent Width of Broad C IV in NGC 3783



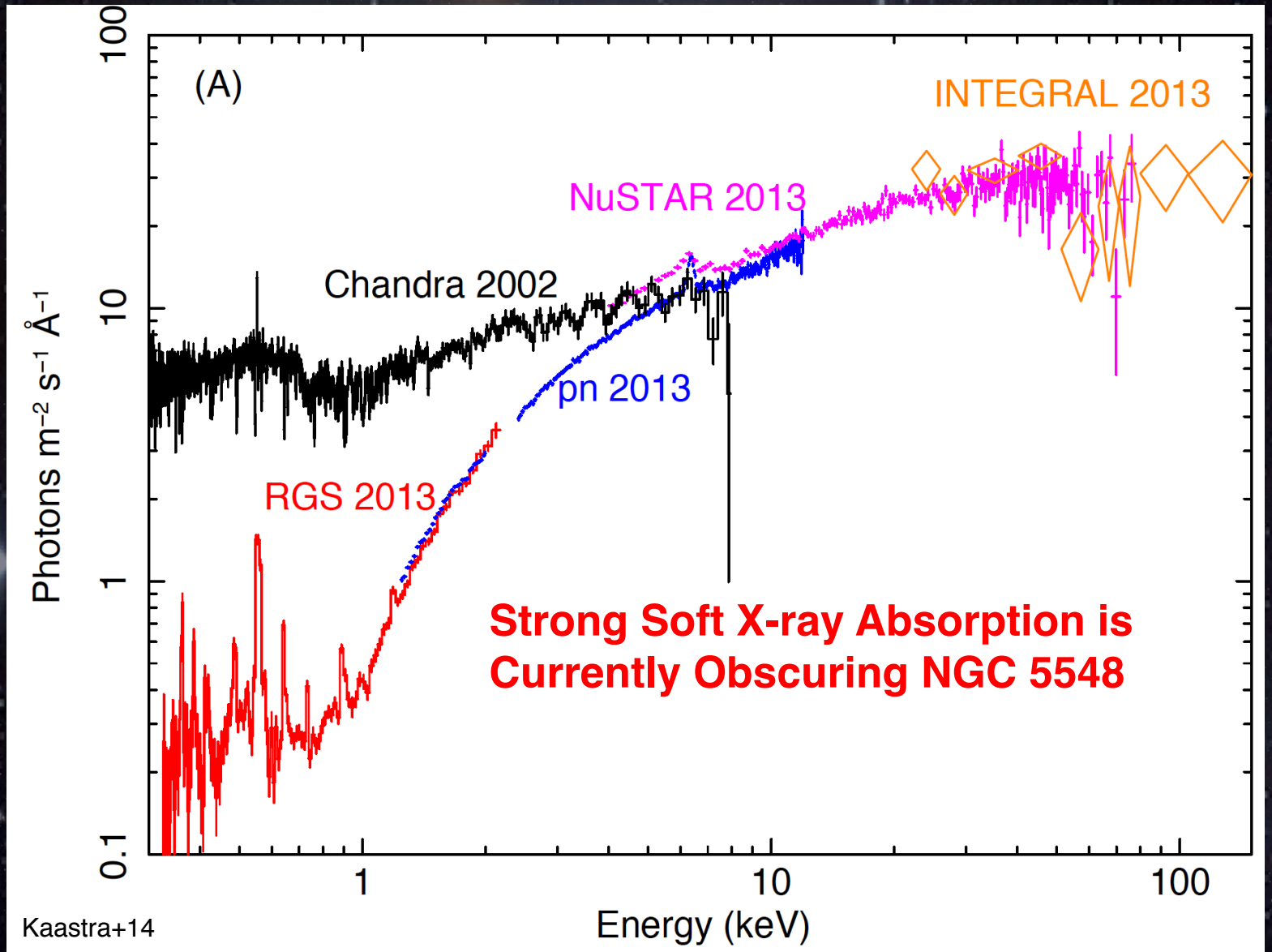
Evolving Structure of the Broad Line Region in NGC 3783



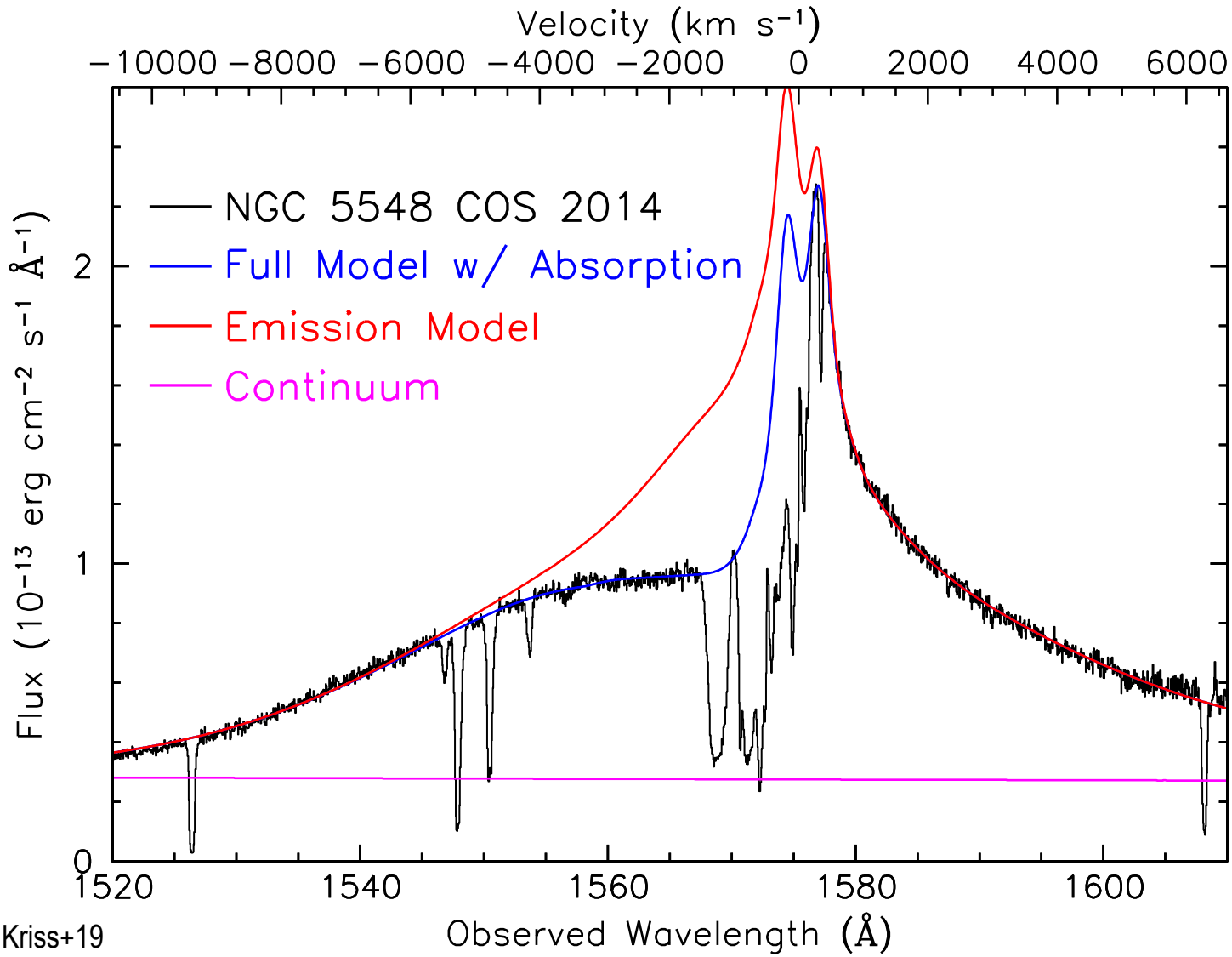
Shapes based on emissivities from the 1992 reverberation mapping campaign (Reichert+94).

- Height based on emission-line EW.
- Peak location based on continuum strength.

Changes in the X-ray Spectrum of NGC 5548

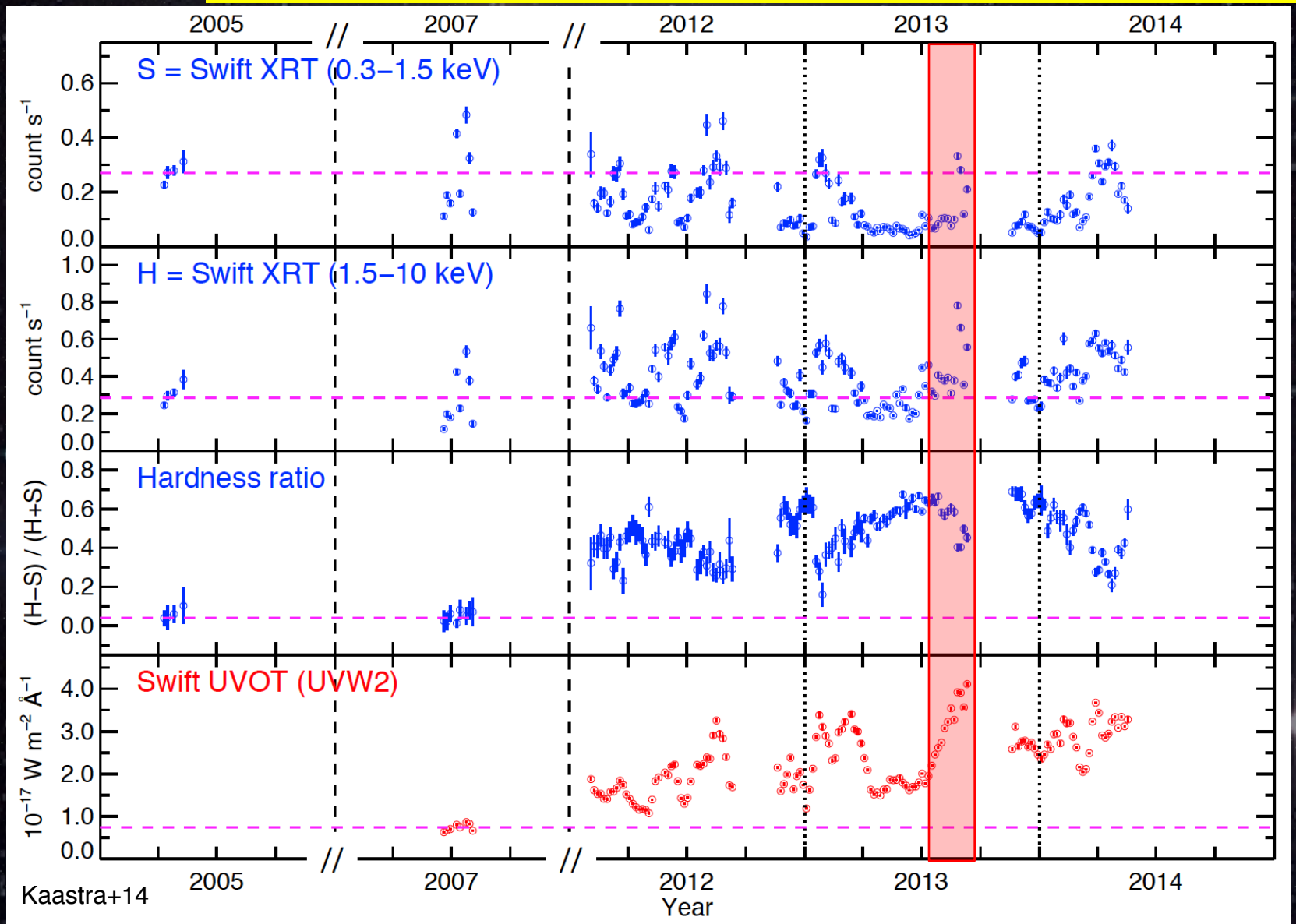


Broad UV Absorption Also Accompanies X-ray Obscuration in NGC 5548

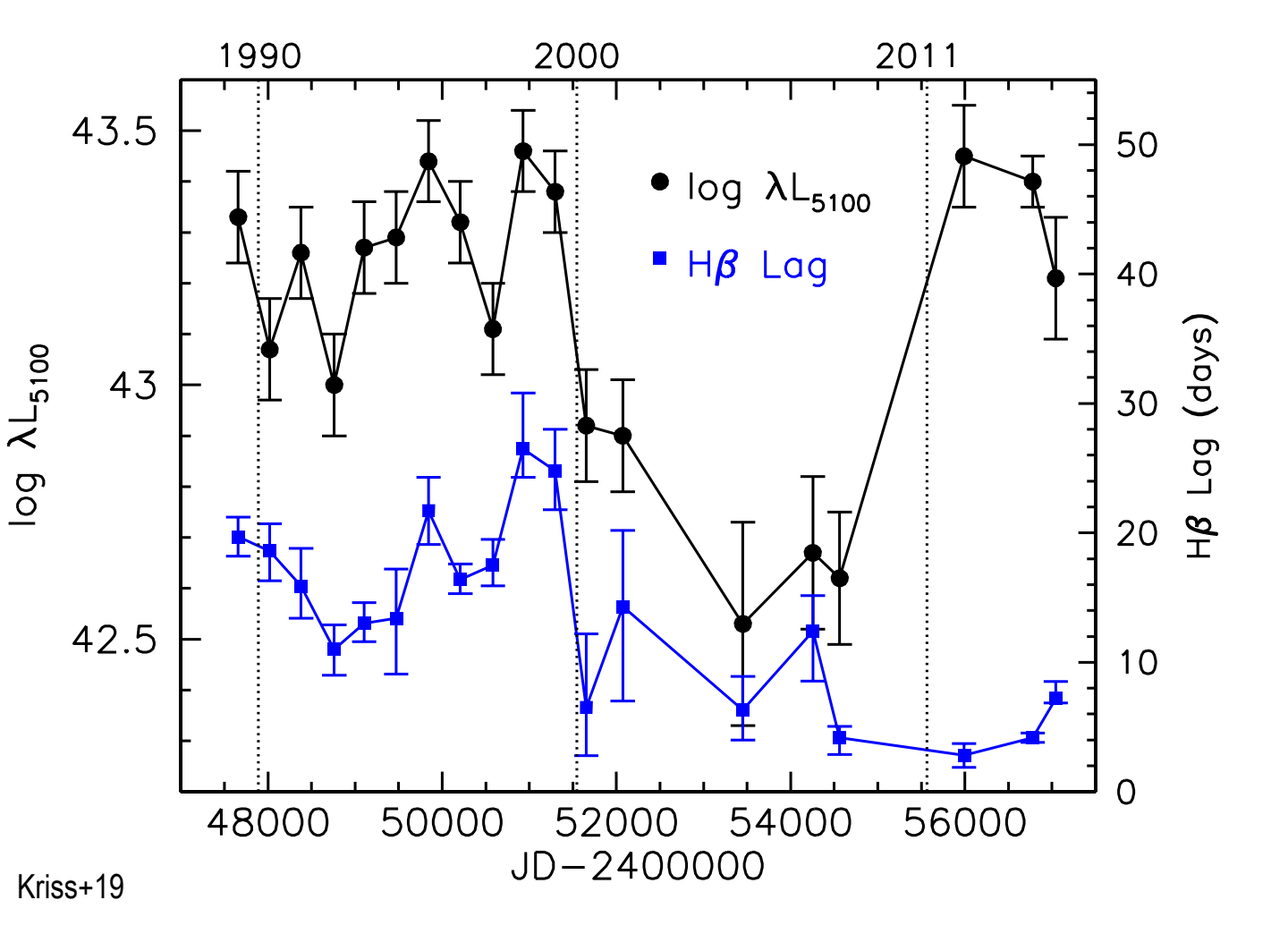


Kriss+19

Time History of Swift Observations of NGC 5548

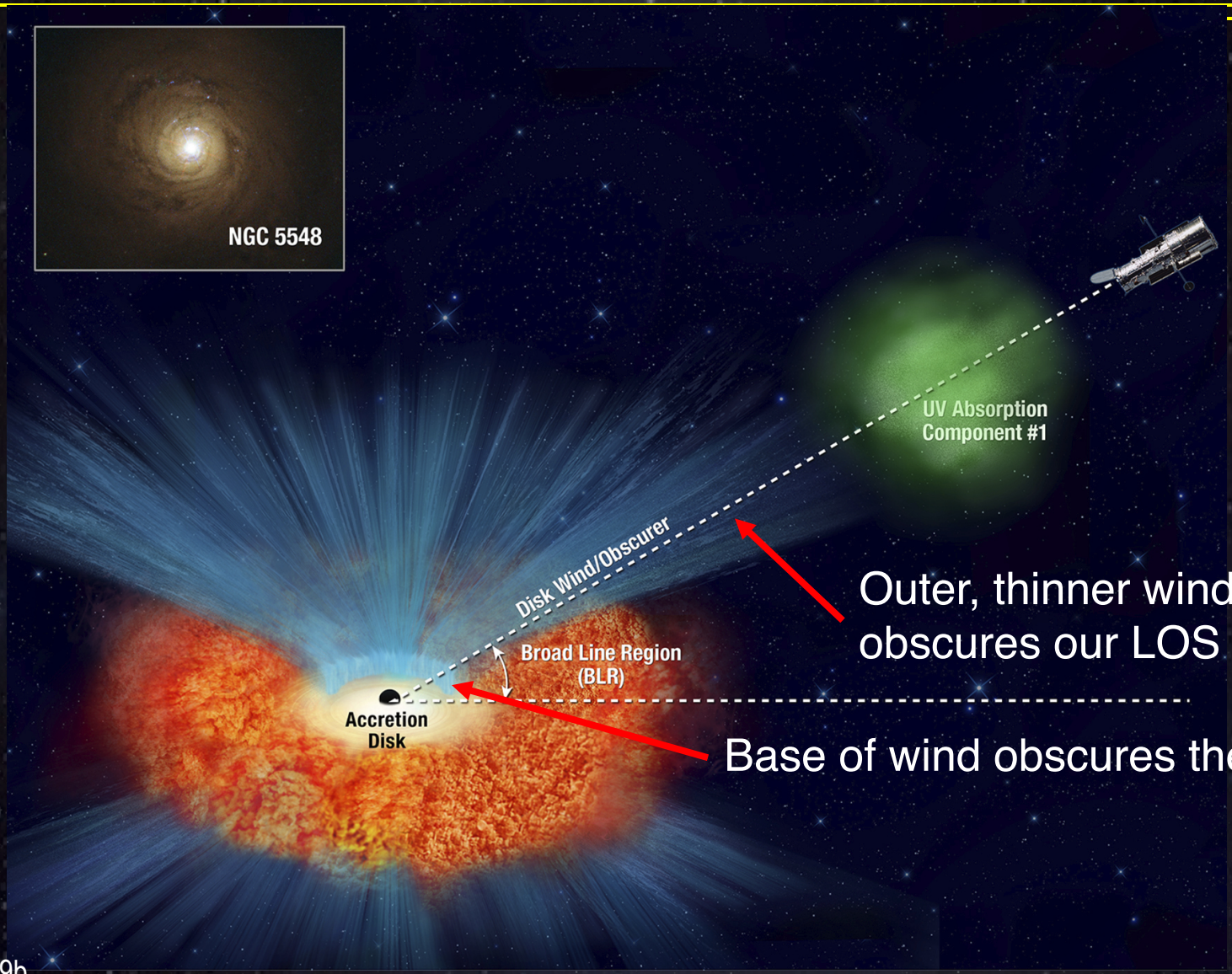


Evolution in the Size of the Broad Hβ Region in NGC 5548



Dalehkar+2018

Concept for the Structure of the BLR and Obscuring Wind in NGC 5548



Dehghanian+19b

Darehkar+2018

Summary

- ★ X-ray plus UV obscuration in AGN is common. Besides the four recent examples, NGC 4151 and NGC 3516 provide historical cases. These 6 cases comprise 25% of the 24 brightest AGN observed in the UV with HST.
- ★ Obscuration is recurrent. This is best seen in NGC 3783 (Swift monitoring study by Kaastra et al. 2018).
- ★ These outflows are much stronger than the typical associated narrow UV absorption lines and X-ray warm absorbers, and may arise in an accretion disk wind, both from the outer and inner parts of the disk.
- ★ Obscuration events+outflows in NGC 5548 and NGC 3783 appear to be triggered by resurgence to a bright state following a low-luminosity period.
- ★ During these low-luminosity periods, the BLR seems to have shrunk. Outflows appear as the BLR is being re-inflated.

Take Away

Observing bright AGN intensively and frequently is providing new insights.

Even though bright AGN are well studied, we still have much to learn, as new intensive observations can be compared to past campaigns to reveal new phenomena.