Transient UV and X-ray Absorption in Seyfert Galaxies and the Relationship to the Broad-Line Region

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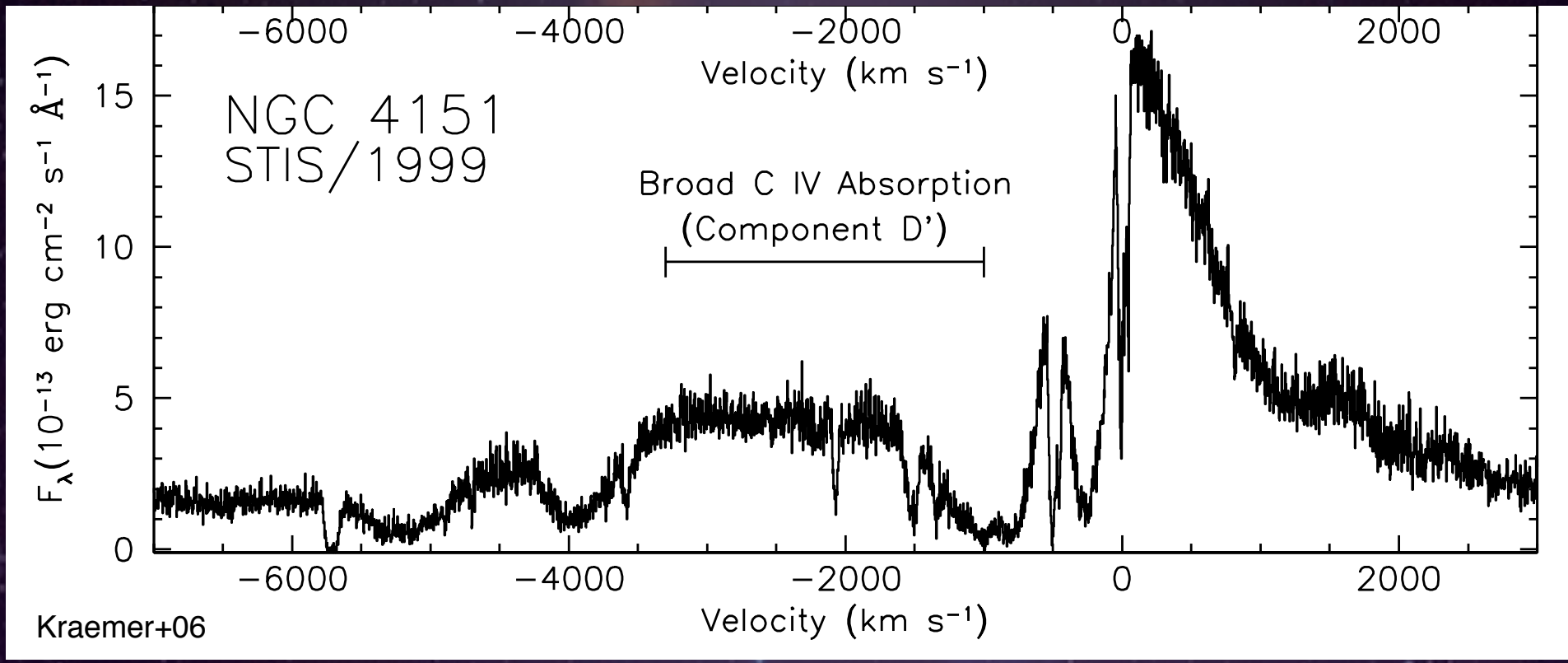
Transient X-ray Absorption in AGN

- **Column-density/partial covering variations common over decades.**
  - Holt et al. (1980) suggest they are caused by broad-line clouds in NGC 4151.
  - Discrete X-ray eclipse events seen in several objects over the last decade, e.g.
    - NGC 1365 (Risaliti et al. 2002)
    - NGC 3227 (Lamer et al. 2003)
    - NGC 7582 (Bianchi et al. 2009)

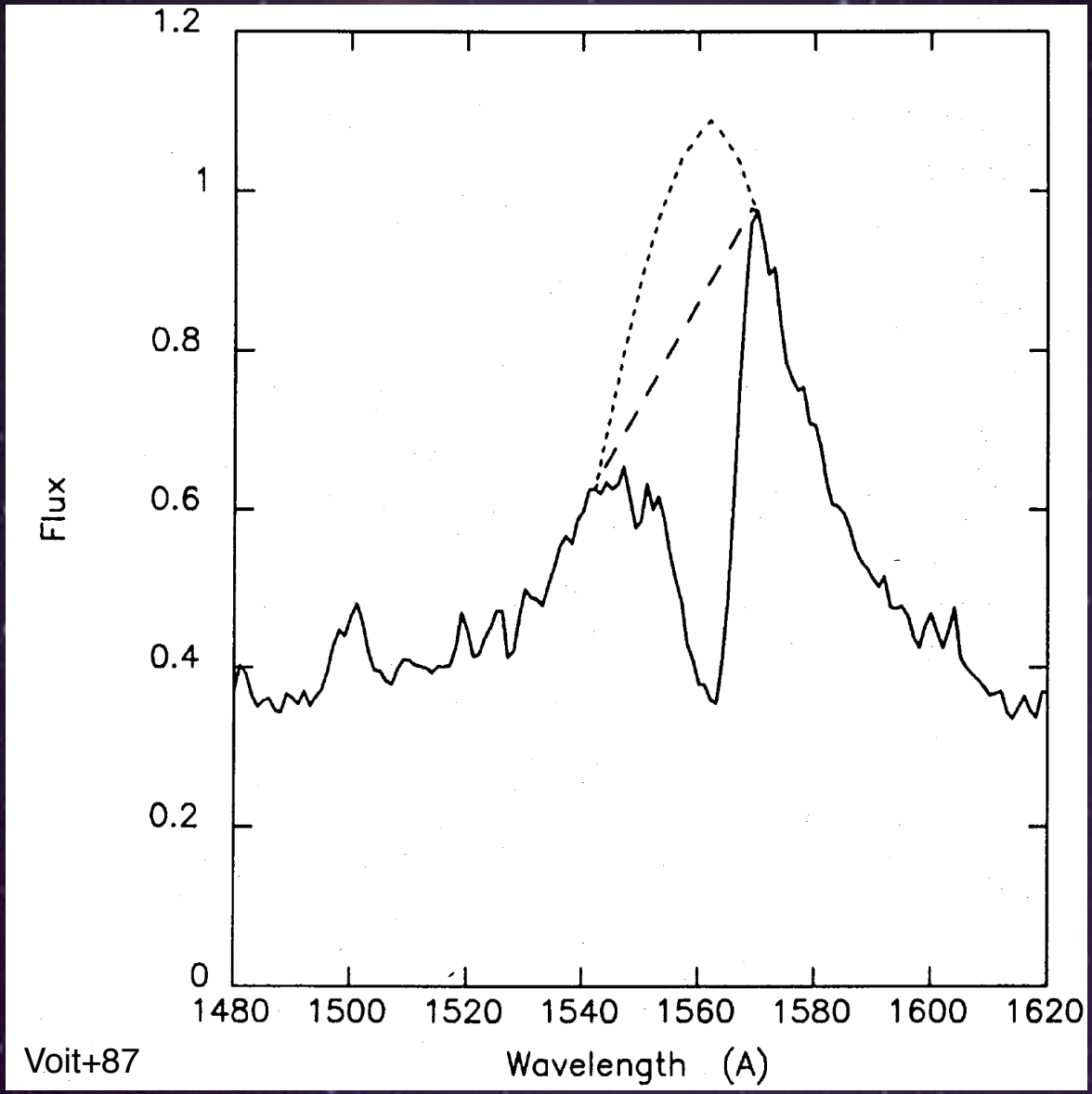
- **Markowitz et al. 2014 study of archival RXTE observations**
  - 12 events in 8 objects
  - Probability 0.006 for Type Is, 0.110 for Type IIs
  - Locations appear to be the outer BLR to the torus based on timescales

- **These objects are Type 1.5 to 2 Seyferts, and there typically are no simultaneous UV observations.**

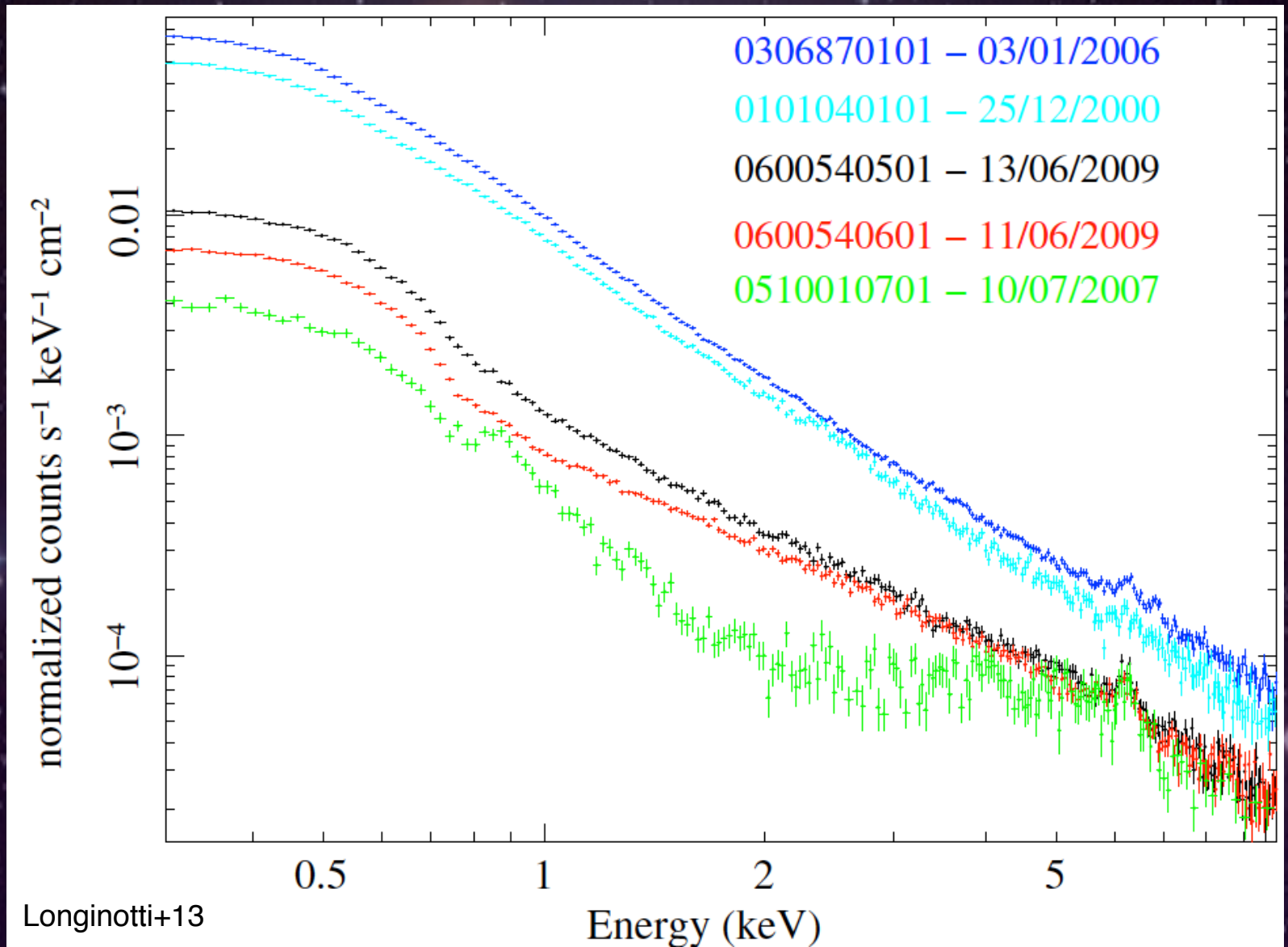
Broad C IV Absorption in NGC 4151



Broad C IV Absorption in NGC 3516 (Observed with IUE)

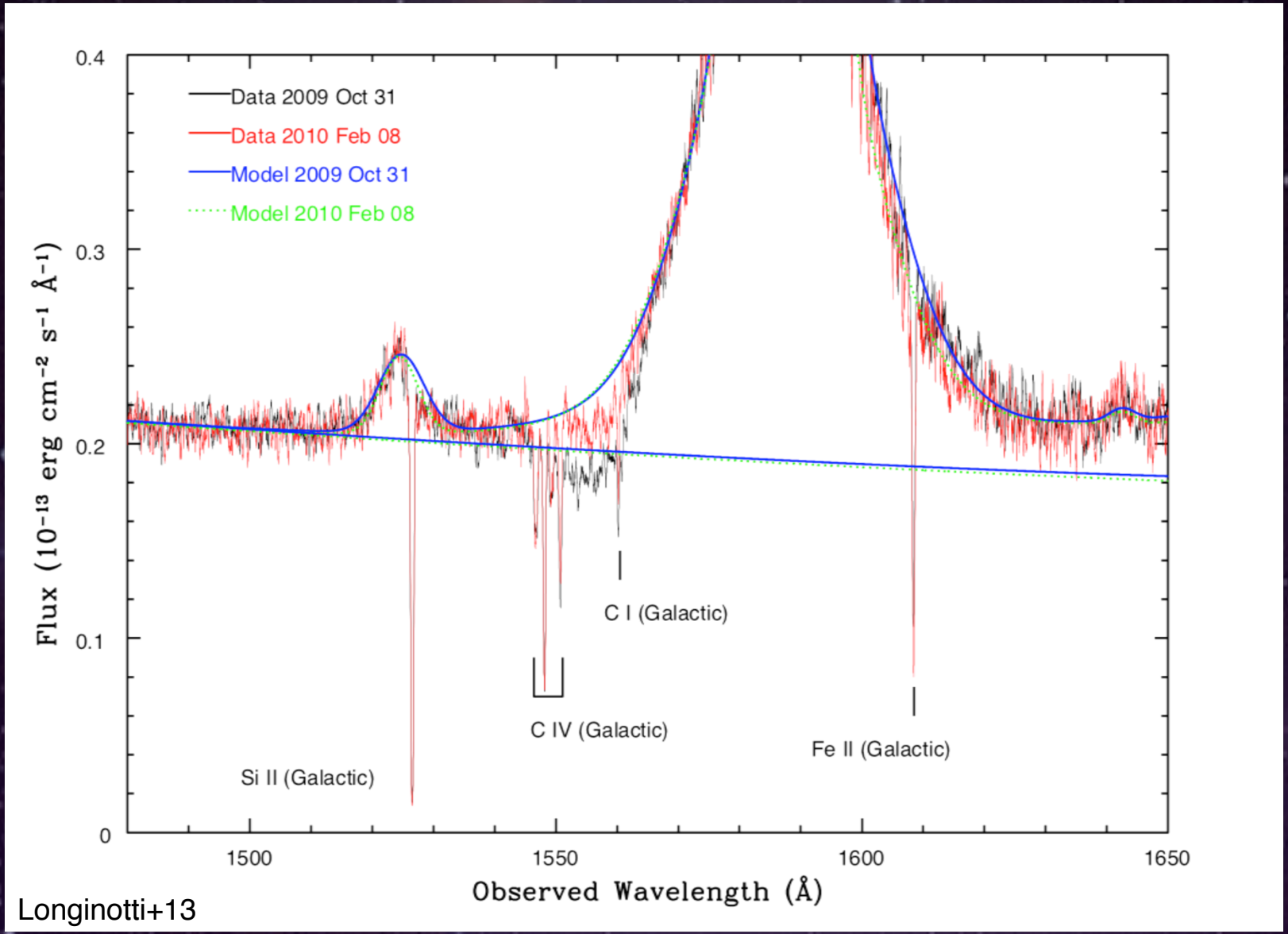


X-ray Absorption in Mrk 335 (A previously never-absorbed Seyfert 1)



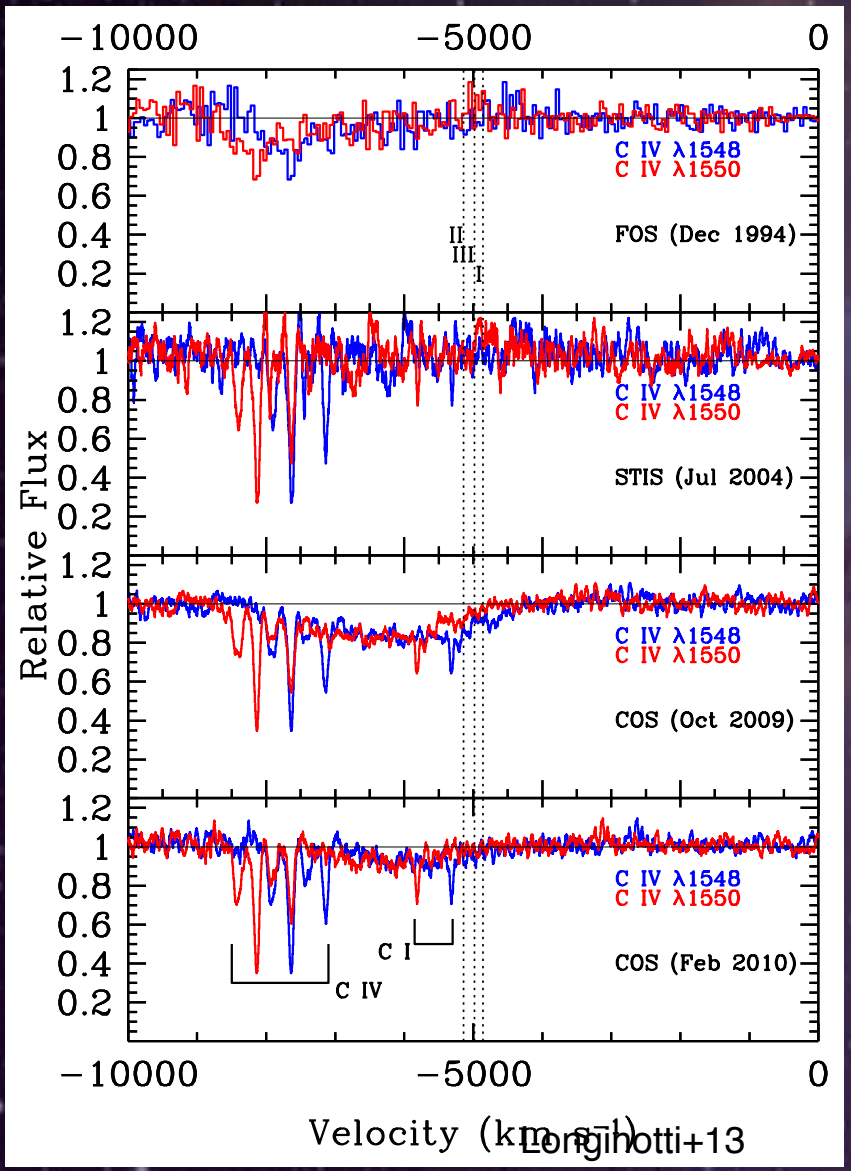
Longinotti+13

Broad C IV Absorption in Mrk 335
(Which never showed any prior UV absorption either.)



Longinotti+13

Normalized C IV Absorption Profiles in Mrk 335

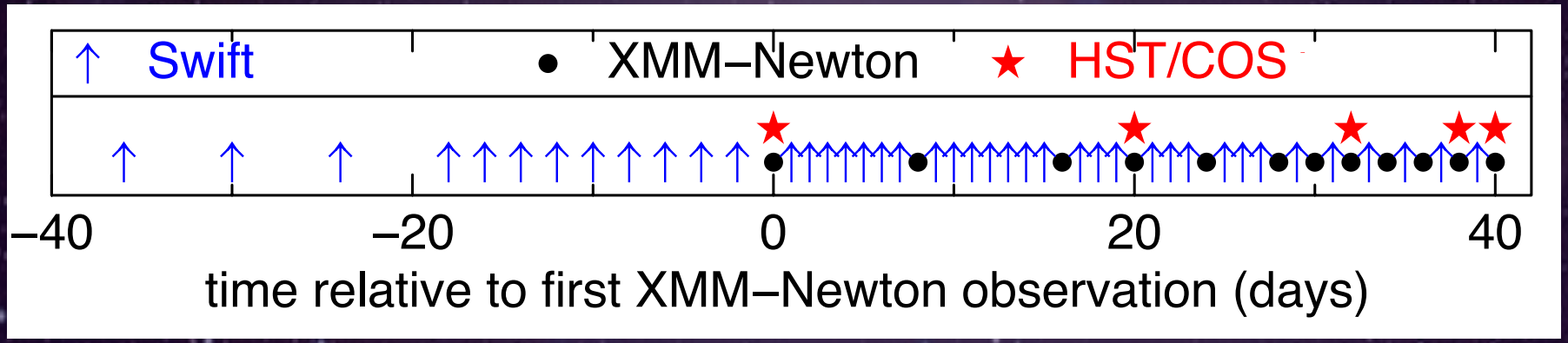


Longinotti+13

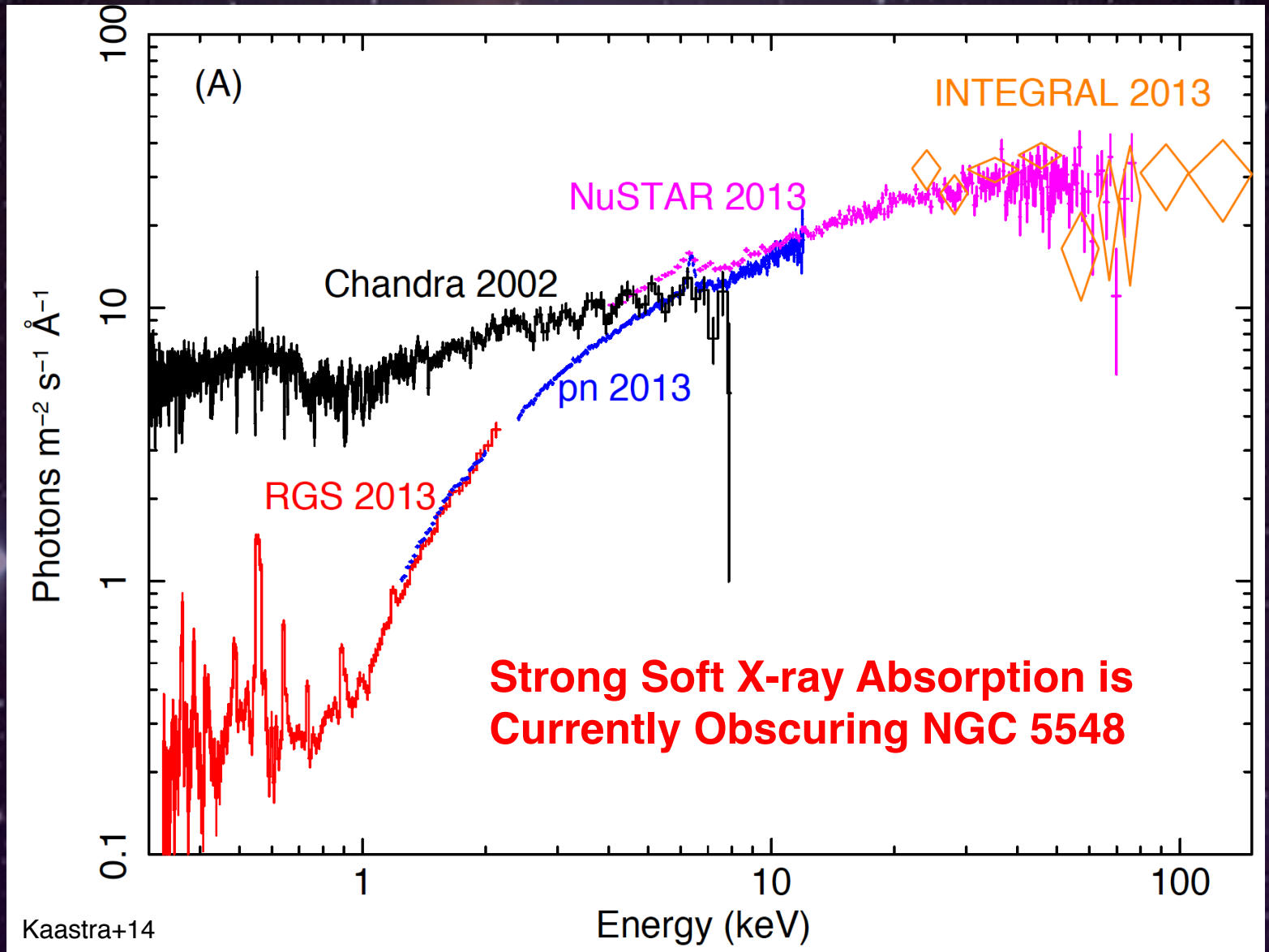
- ★ **Distance is unknown, but, if it is near the BLR, e.g., 0.01 pc:**
- ★ $\dot{M}_{out} = 4\pi\,\Delta\Omega\, r\, N_H\, \mu m_p\, v_{out}$
  $= 0.05\ M_\odot yr^{-1}$
  $(r/0.01\ pc)(N_H/10^{22})(v/5000)$
- ★ $L_k = \frac{1}{2}\,\dot{M}_{out}\, v_{out}^2 = 3.9 \times 10^{41}\ erg\ s^{-1}$
- ★ $L_{bol} = 3\times10^{44}\ erg\ s^{-1}$, so
  - $L_k/L_{bol} = 0.13\%$

X-ray/UV Campaign on NGC 5548 (Summer 2013)

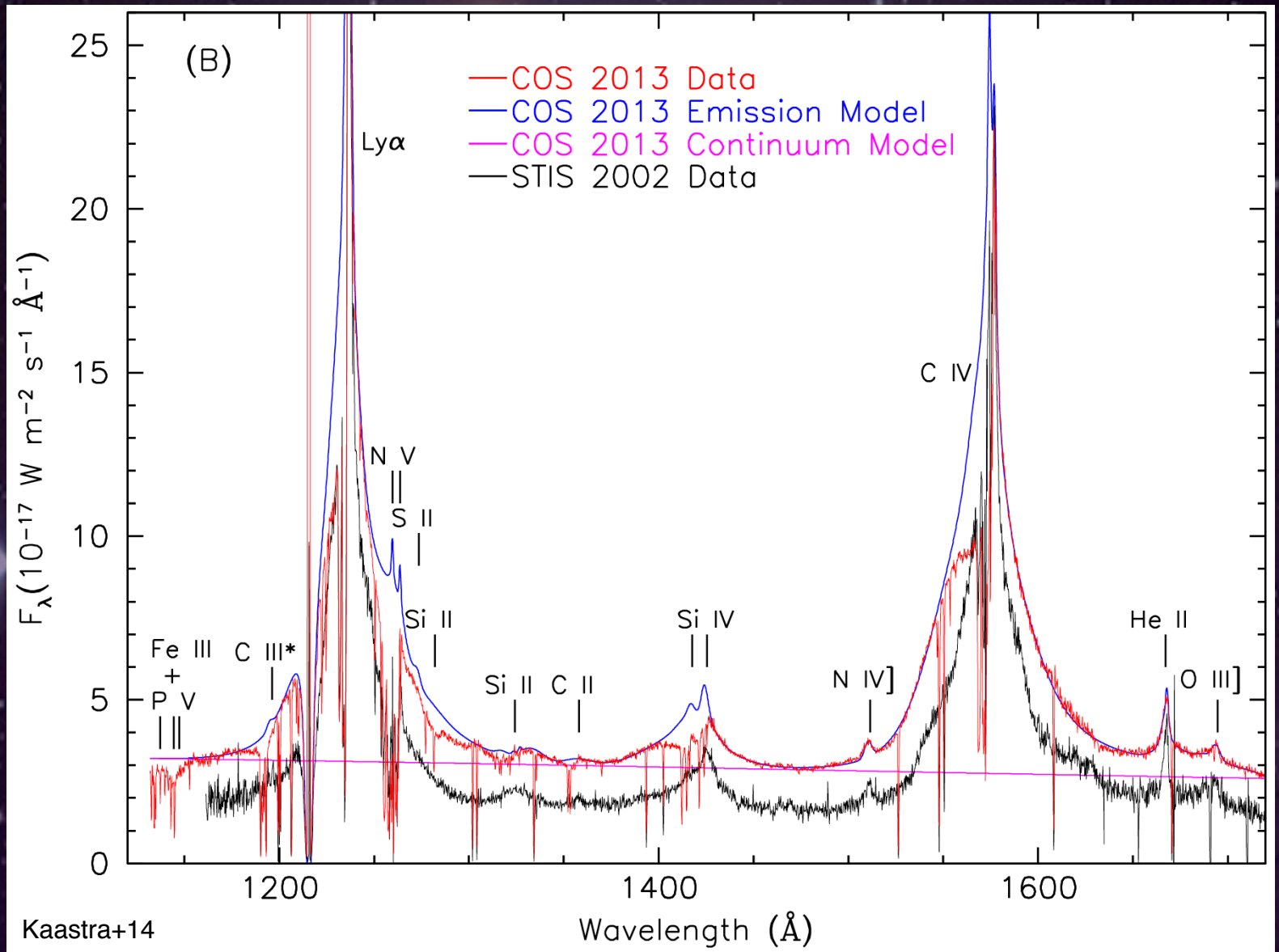
- ★ **XMM/Newton (Kaastra)**
  - 10 x 50 ks at 8, 4, and 1-day intervals with EPIC, PN, and RGS
  - 2 more visits in winter 2014, 4—6 months later
- ★ **Swift (Kaastra)**
  - Simultaneous continuum monitoring in X-ray and UV w/ XRT & UVOT
  - 12 x 1 ks at 4-day intervals establishing baseline before XMM
  - Daily during the XMM campaign
- ★ **HST (Kaastra)**
  - 5 2-orbit visits with HST/COS at 20, 12, 3, and 1-day intervals.



Changes in the X-ray Spectrum of NGC 5548

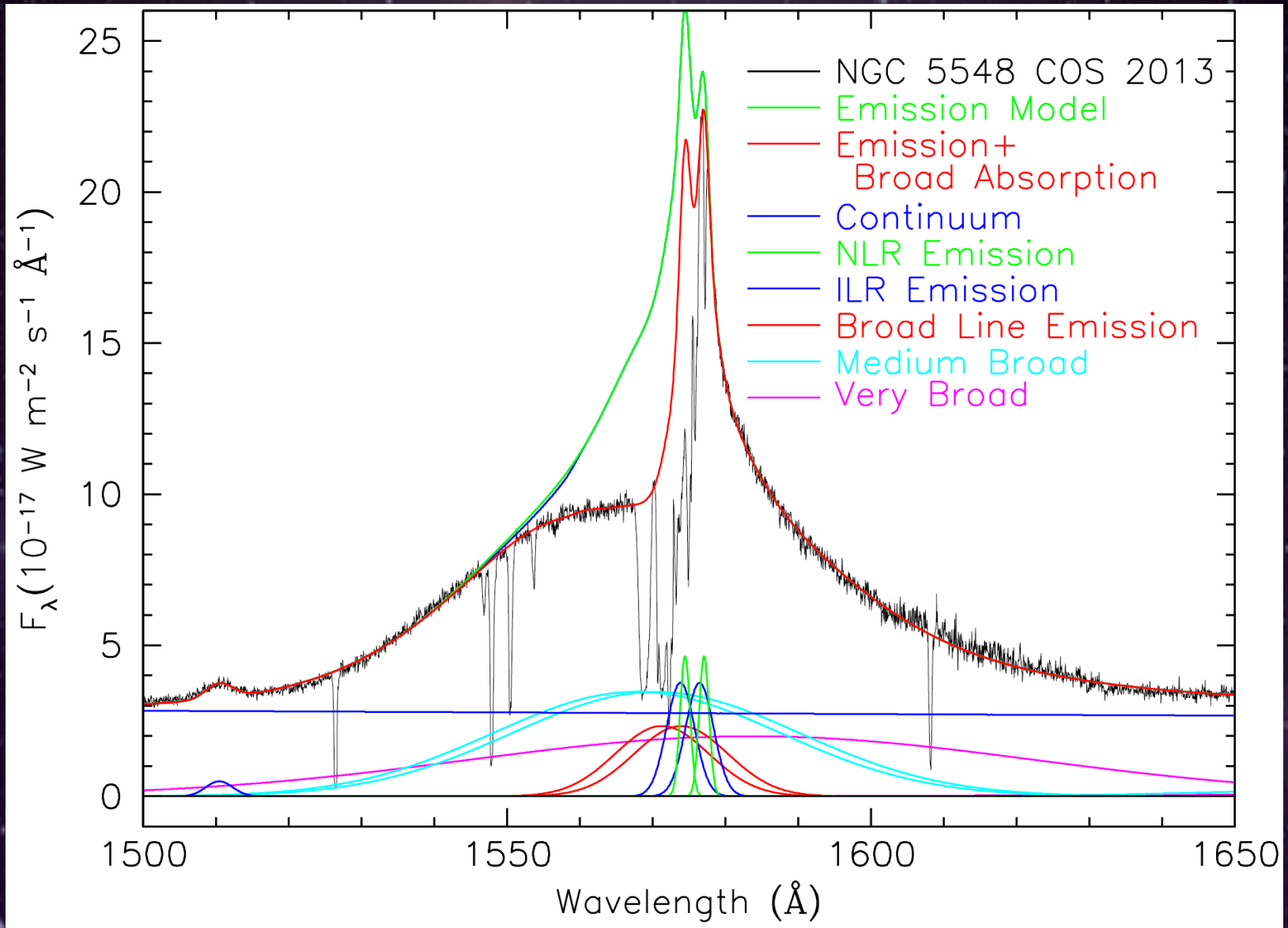


Broad UV Absorption Features in NGC 5548

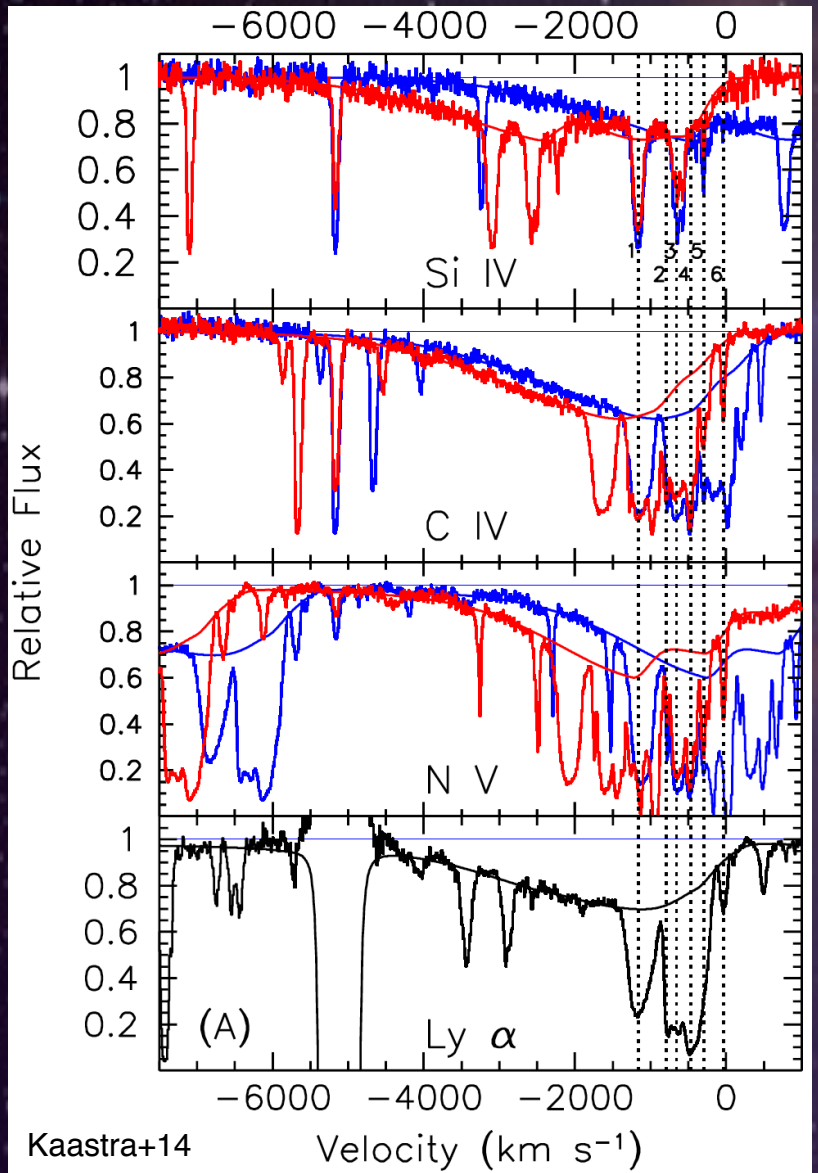


Kaastra+14

Broad C IV Absorption in NGC 5548



Normalized Broad Absorption Profiles in NGC 5548

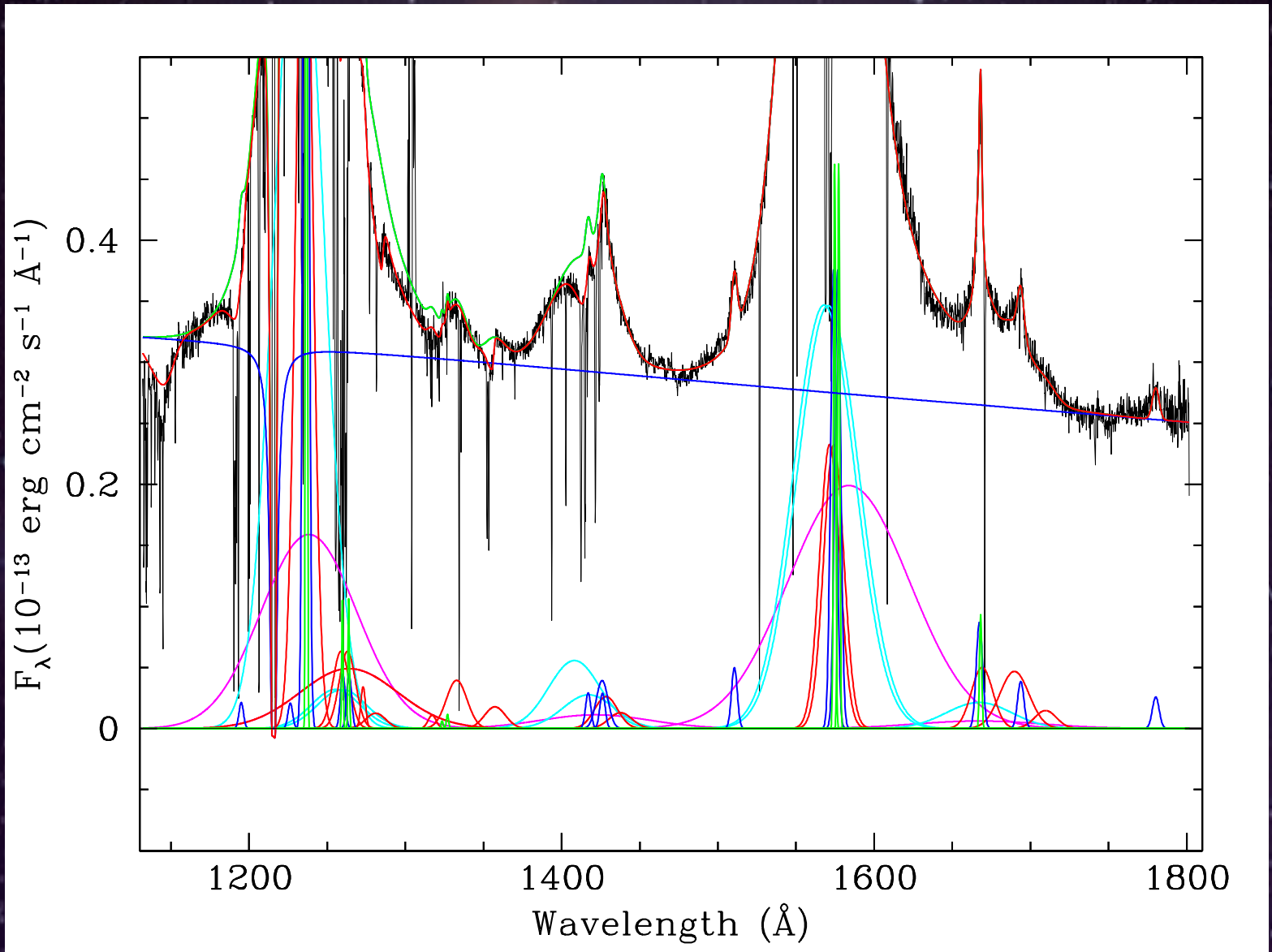


- **Distance is unknown, but, if it is near the BLR, e.g., 0.01 pc:**
- $\dot{M}_{out} = 4\pi\,\Delta\Omega\, r\, N_H\, \mu m_p\, v_{out}$
  $= 2.5\times10^{-6}\ M_\odot yr^{-1}$
  $(r/0.01\ pc)(N_H/10^{22})(v/5000)$
- $L_k = \frac{1}{2}\,\dot{M}_{out}\, v_{out}^2 = 1.9\times10^{37}\ erg\ s^{-1}$
- $L_{bol} = 1\times10^{44}\ erg\ s^{-1}$, so
  - $L_k/L_{bol} = 1.9\times10^{-7}$

Why is it Absorption, and not Changes in the Emission-Line Profile?

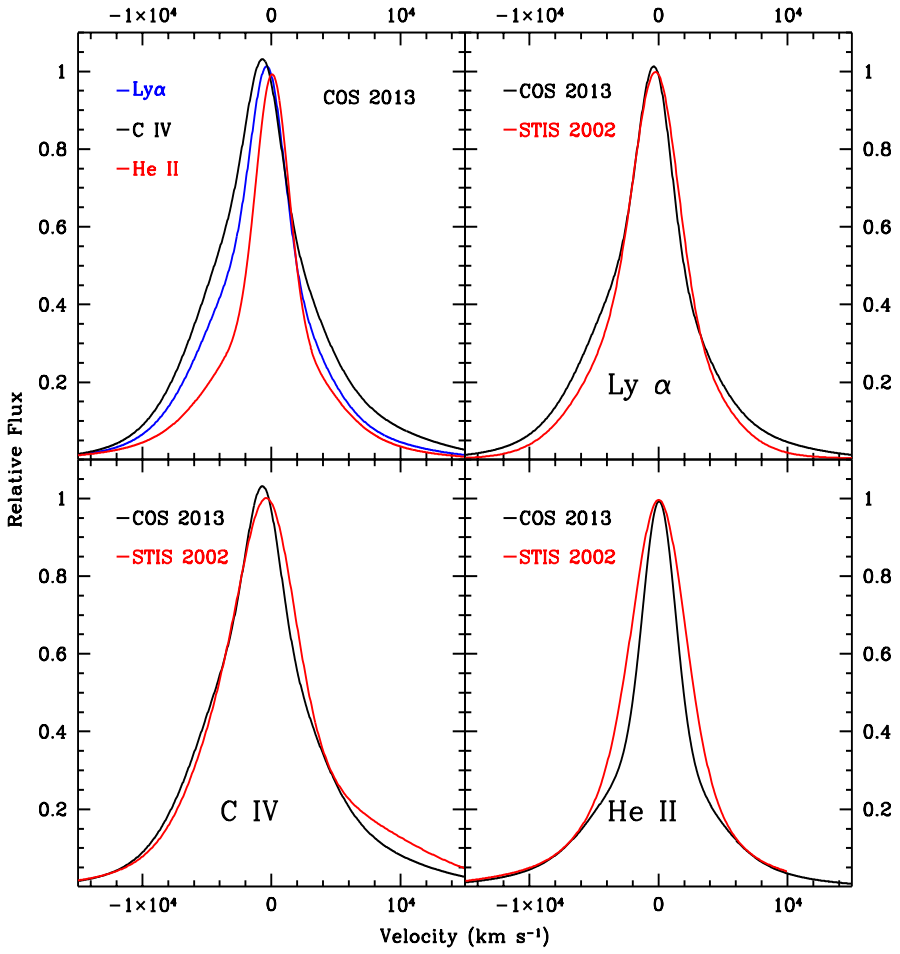
- ★ All ground-state-connected permitted transitions show absorption.
- ★ No forbidden or semi-forbidden lines show absorption.
- ★ Absorption in weaker emission lines also absorbs the continuum.
- ★ If the profiles are modeled with emission+absorption, similar emission profiles fit both archival data and the He II λ1640 profile.

Broad UV Absorption Lines in NGC 5548

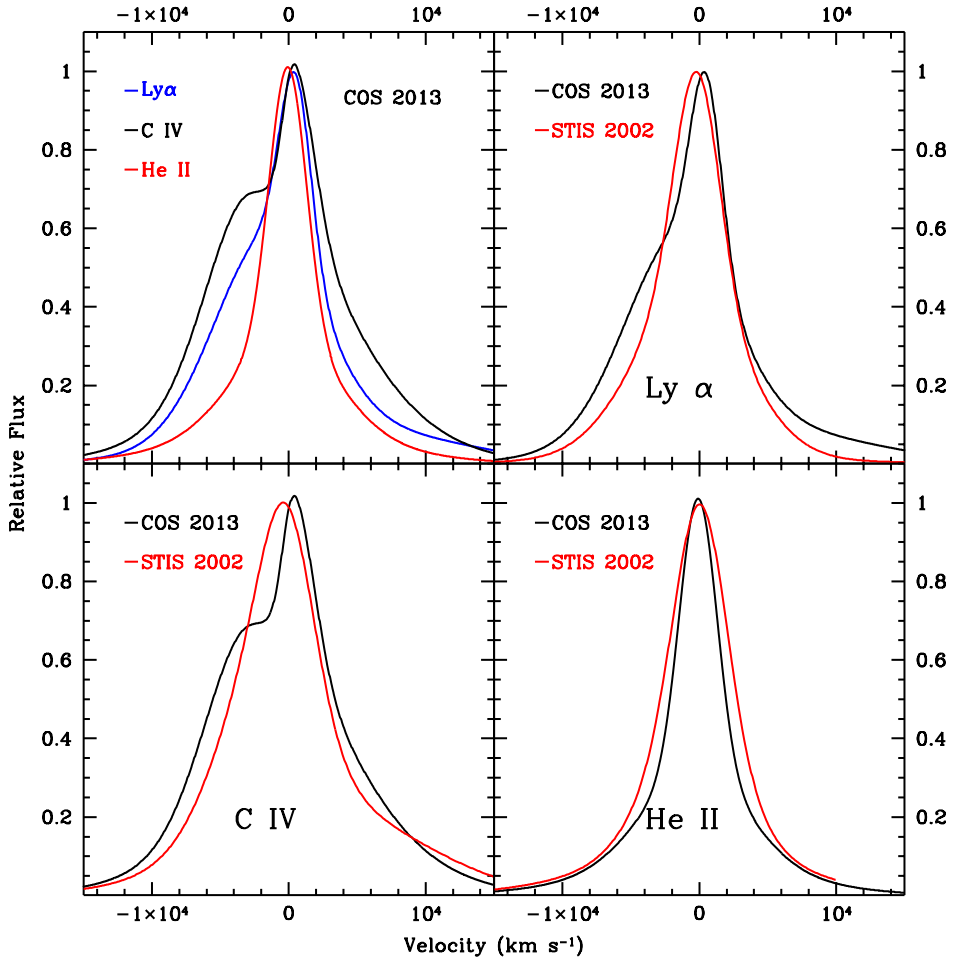


Underlying Broad Emission-Line Profiles

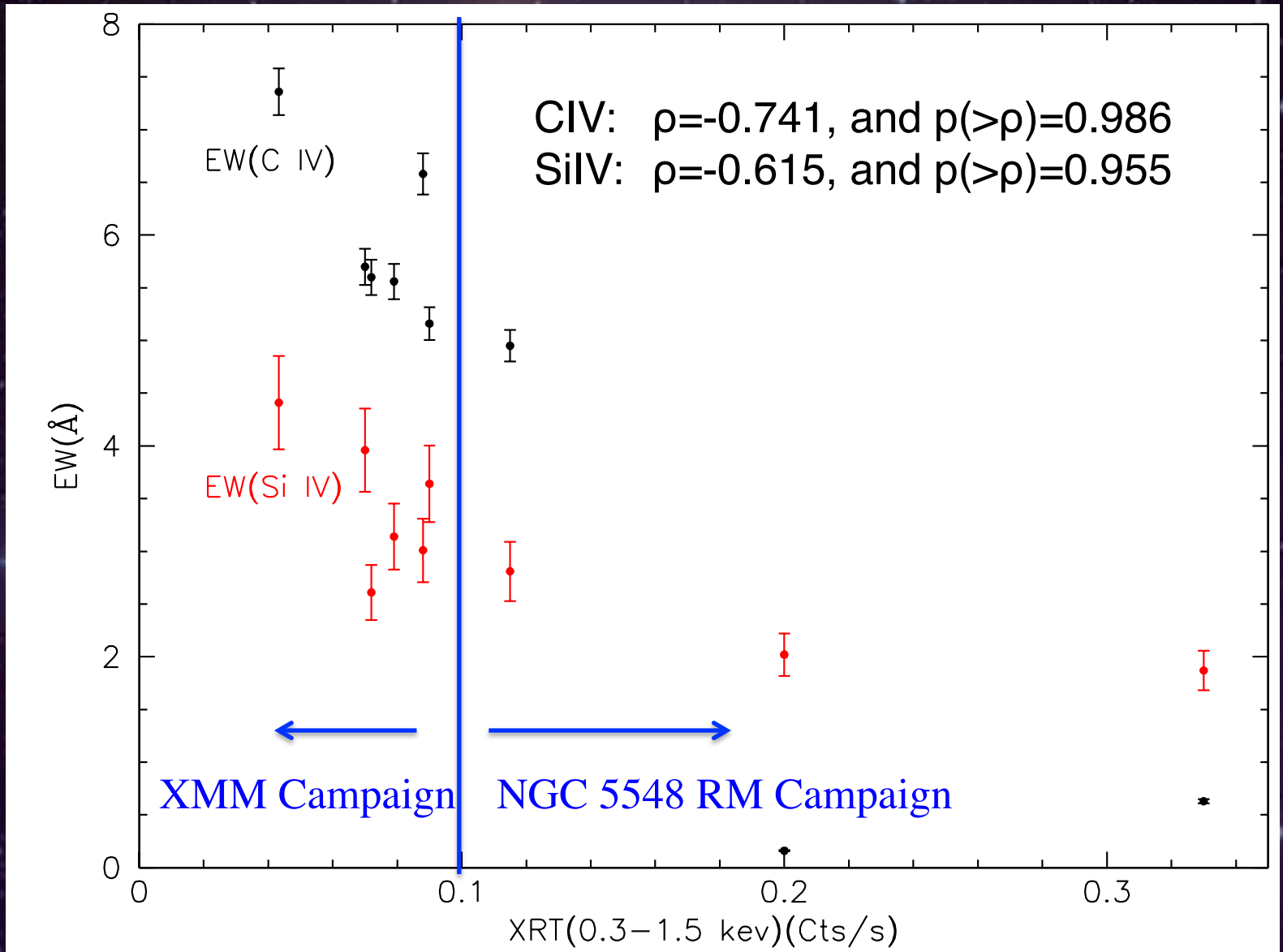
Asymmetry modeled as absorption



Model with no absorption



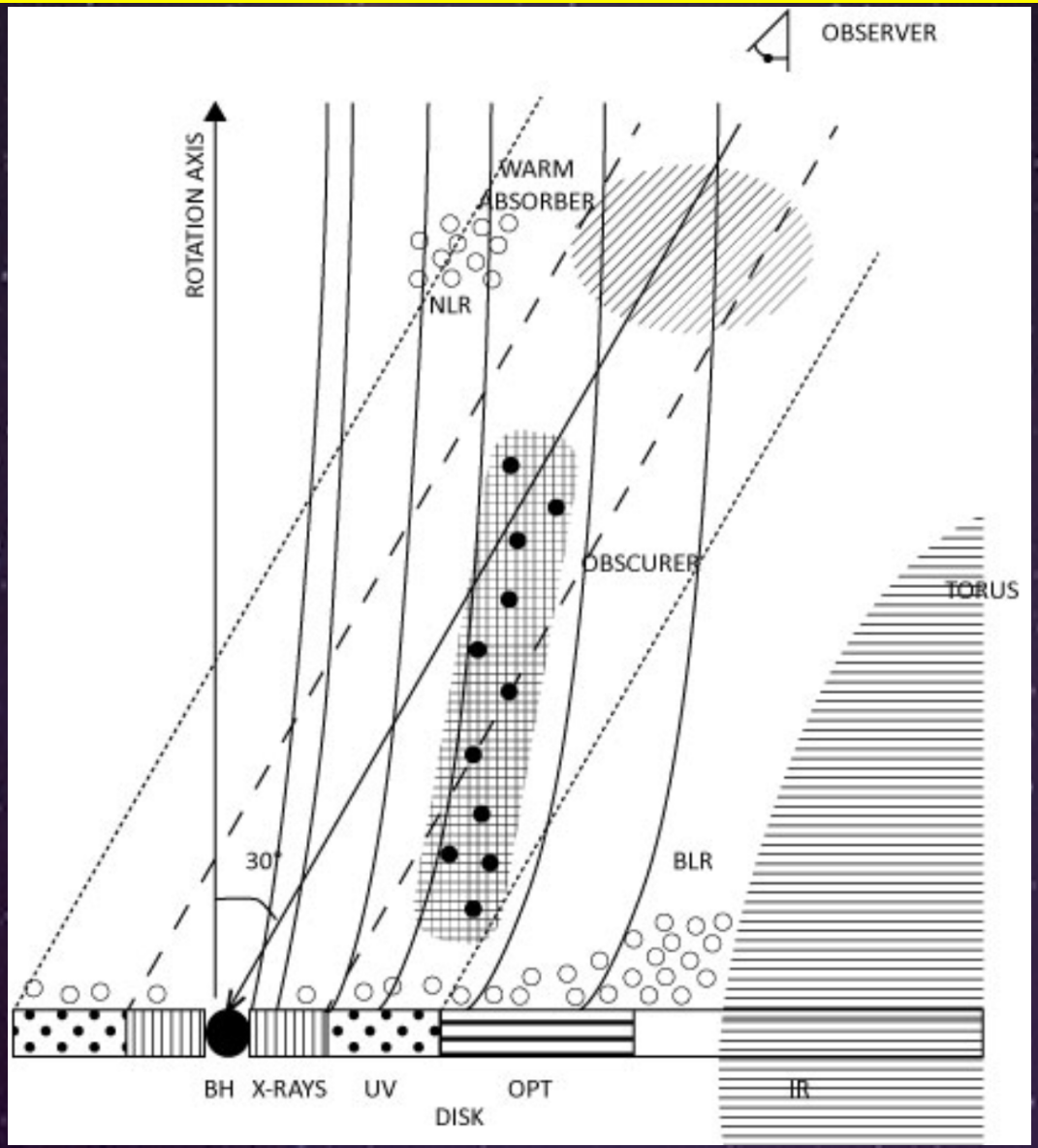
Broad Absorber Covering Fraction Anticorrelates with the Soft X-ray Flux



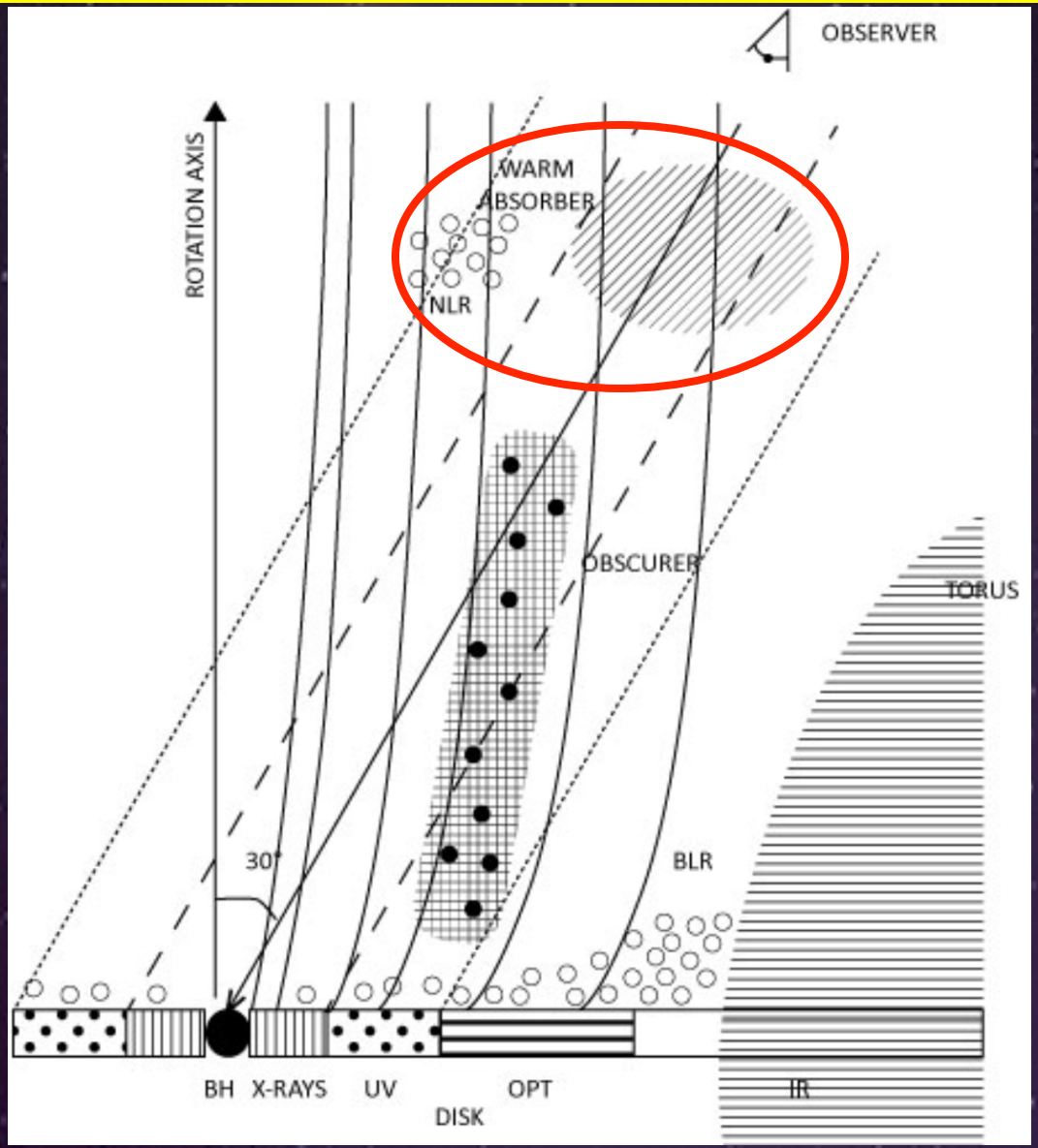
Where is the Broad Absorber in NGC 5548?

- **The X-ray obscurer has multiple components.**
  - Obscurer #1, with an ionization parameter compatible with the broad UV absorption lines, has a covering factor of 86%.
  - Obscurer #2, which is nearly neutral, has a smaller covering fraction of only ~30%.
- **The C IV and Ly α broad absorbers are deeper than the continuum, so the UV absorber must cover both the continuum and the BLR.**
  - The UV covering factor of the BLR is at least 18%, but no more than 40%.
- **Changes in the X-ray obscuration on timescales of ~2 days are consistent with clumps in the obscurer crossing the line of sight at Keplerian velocities typical of the BLR (3000 km s^{-1}).**
- **Outflow velocities of up to 5000 km s^{-1} are consistent with a launch point in the BLR.**

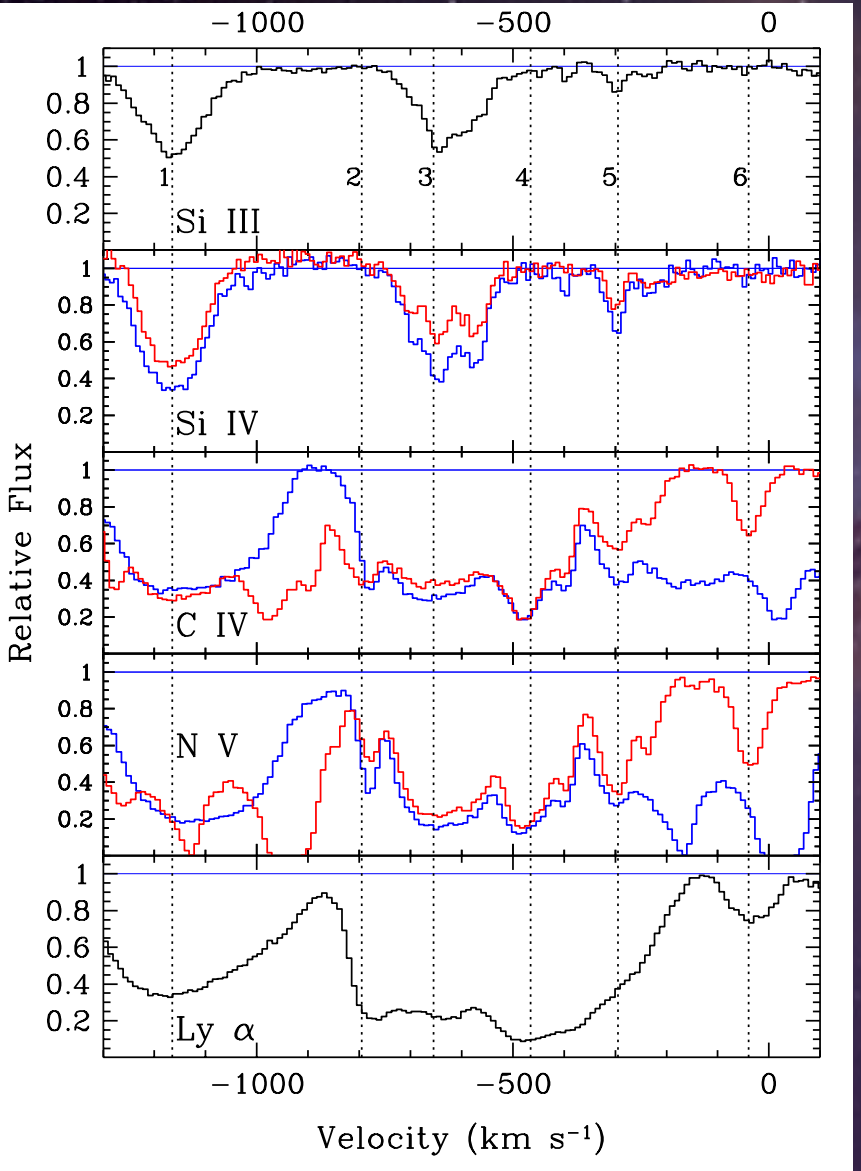
Cartoon Showing the Location of the Obscurer in NGC 5548



The Obscurer in NGC 5548 also Shadows the Warm Absorbers

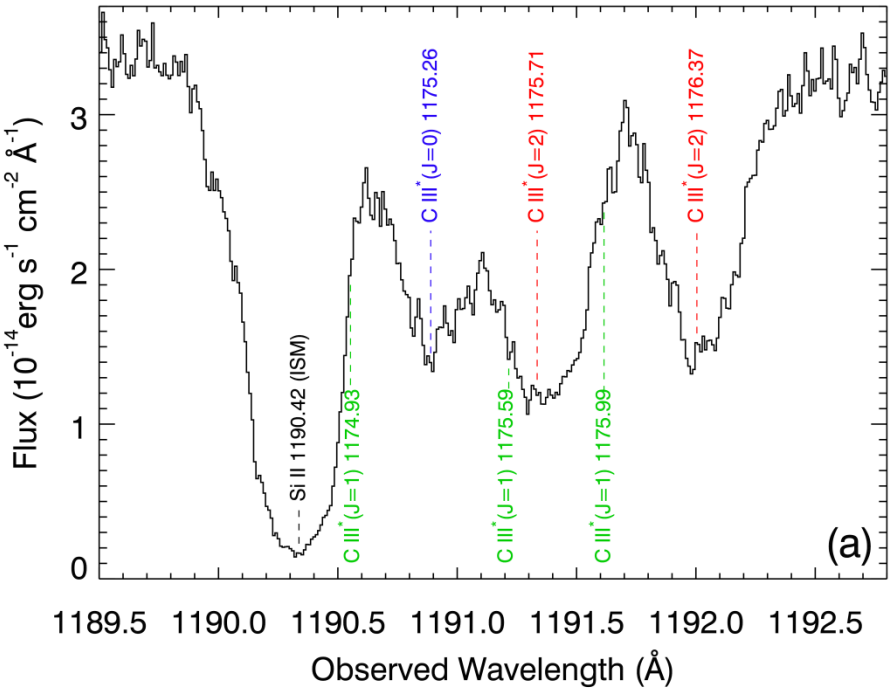


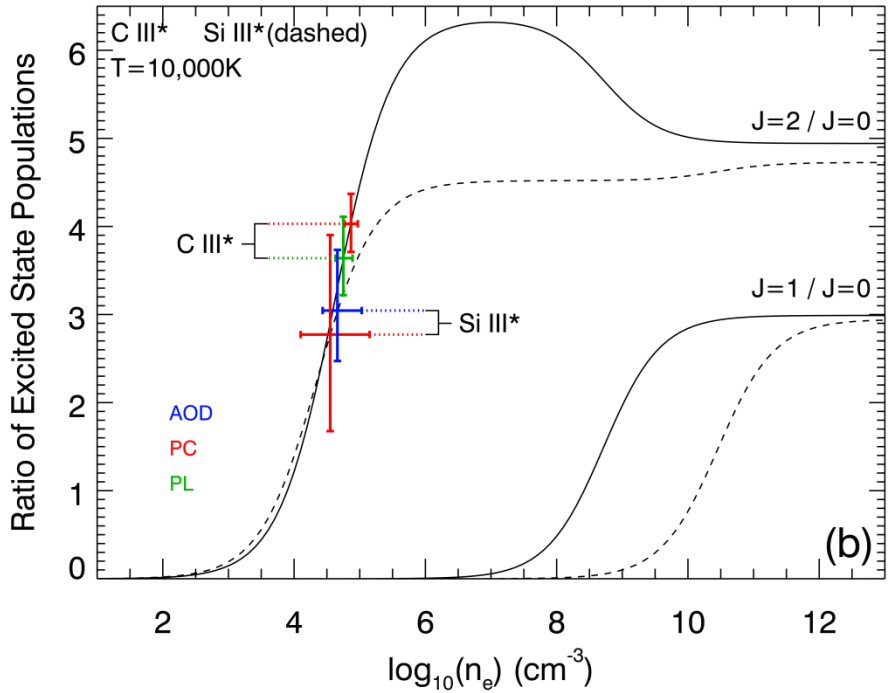
Normalized Profiles of Absorption in NGC 5548

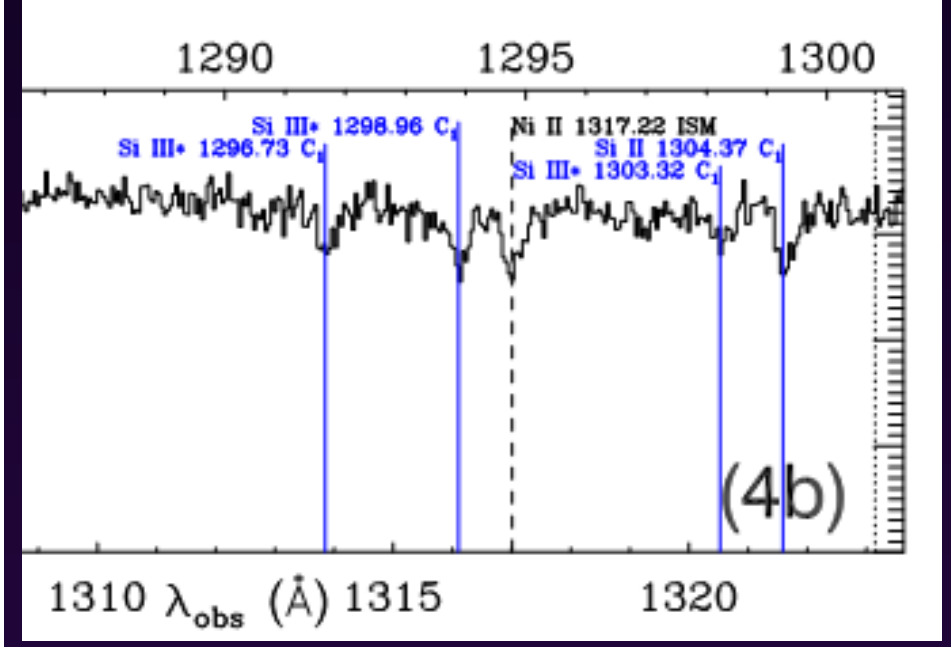


In addition to these major features, for component #1 we also see the following:

- P V λλ1117,1128
- P III* λ1344
- C II λ1334 & C II* λ1335
- C III* λ1176 (several lines)
- Si II & Si II* (many transitions)
- Si III* λ1298 (several lines)
- S III and SI II* (many transitions)
- Fe III and Fe III* (many transitions)
- Al II λ1670







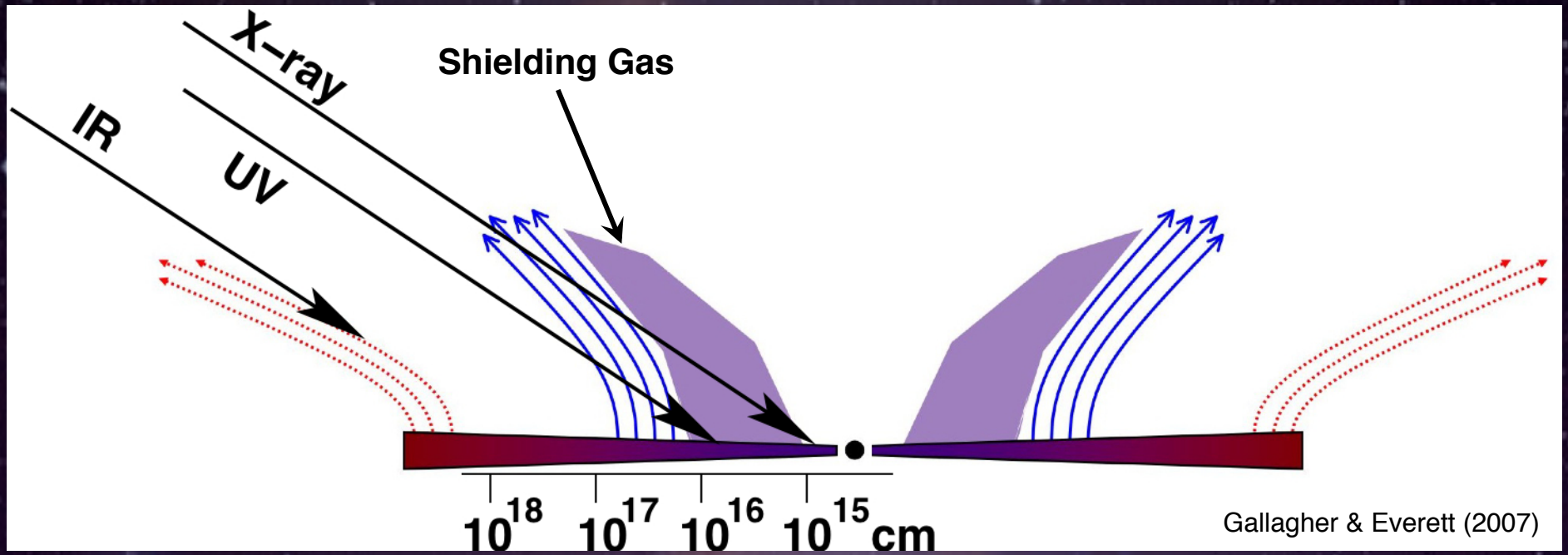
★ Density-sensitive lines in Component #1 give:
$\log n_e = 4.8 \pm 0.1$

★ For log(U)=−1.5,

distance R=3 pc

★ This is comparable to the NLR size of 1—3 pc (Peterson et al. 2013)

Is this a Disk Wind?



- BALQSOs are X-ray faint, so spectra are low S/N. Data are consistent with heavy X-ray absorption, but they also could be intrinsically faint (Gallagher et al. 2008).
- Heavy X-ray absorption plus broad UV absorption in NGC 5548 could be the long-sought “shielding gas” of disk-wind models for BALQSO outflows.

Summary

- **High velocity outflows with v > 5000 km/s exist in typical Seyfert 1s.**
  - Despite their high velocities, the mass flux and kinetic luminosity of these outflows make them too weak to influence host galaxy evolution.

- **Nevertheless, high velocity outflows with accompanying X-ray obscuration such as we observed in NGC 5548 illuminate our understanding of more powerful winds in BALQSOs.**
  - These outflows may be illustrating the “shielding gas” mechanism for radiative acceleration of an accretion-disk wind.
  - Variability in the broad UV absorption may be due to transient obscuration of the soft X-ray and EUV ionizing continuum.