UV Absorption in NGC 5548

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STScI

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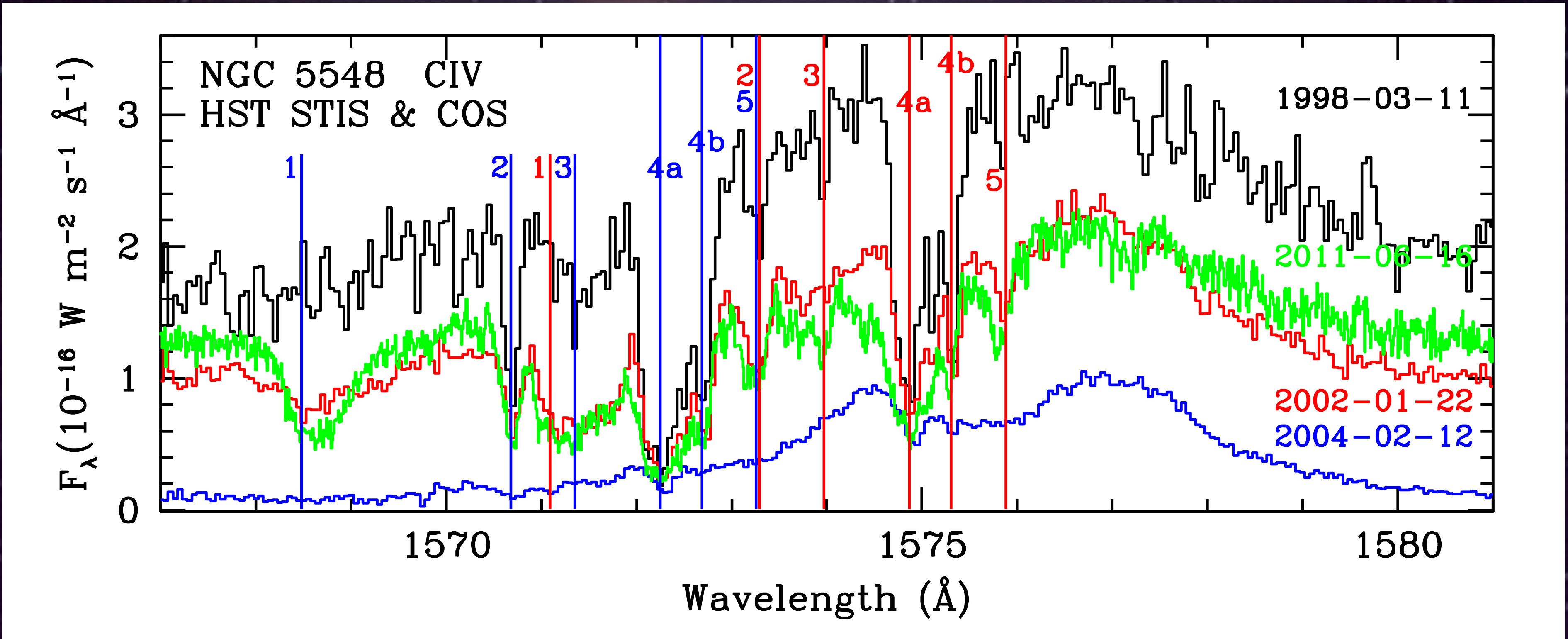
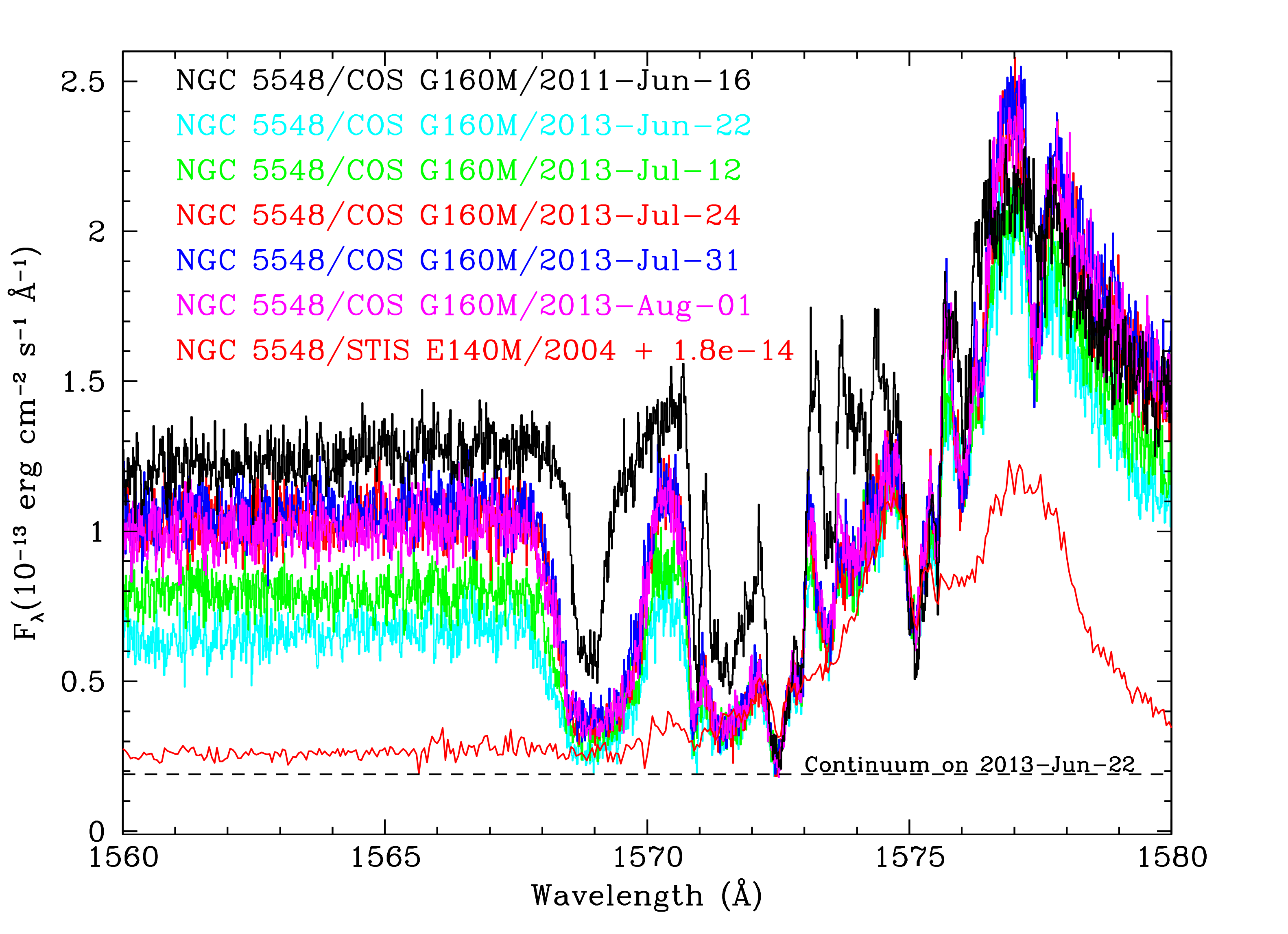
The Narrow Absorption Components in NGC 5548

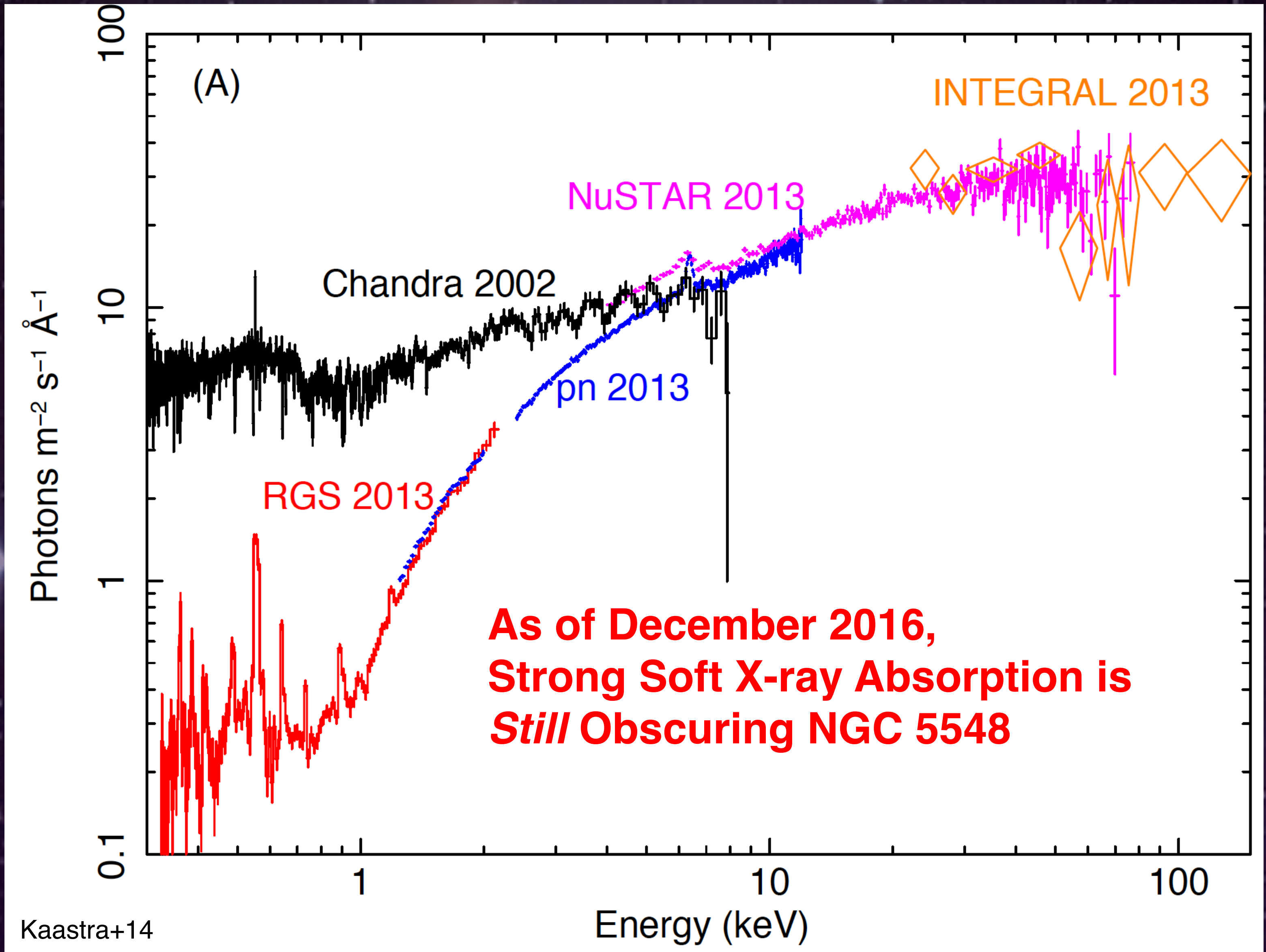


This is the C IV region prior to the 2013 XMM campaign.
Absorption components are labeled from high to low velocity.

The Bottoms of the Narrow C IV Absorption Troughs in NGC 5548 *Do Not Vary*

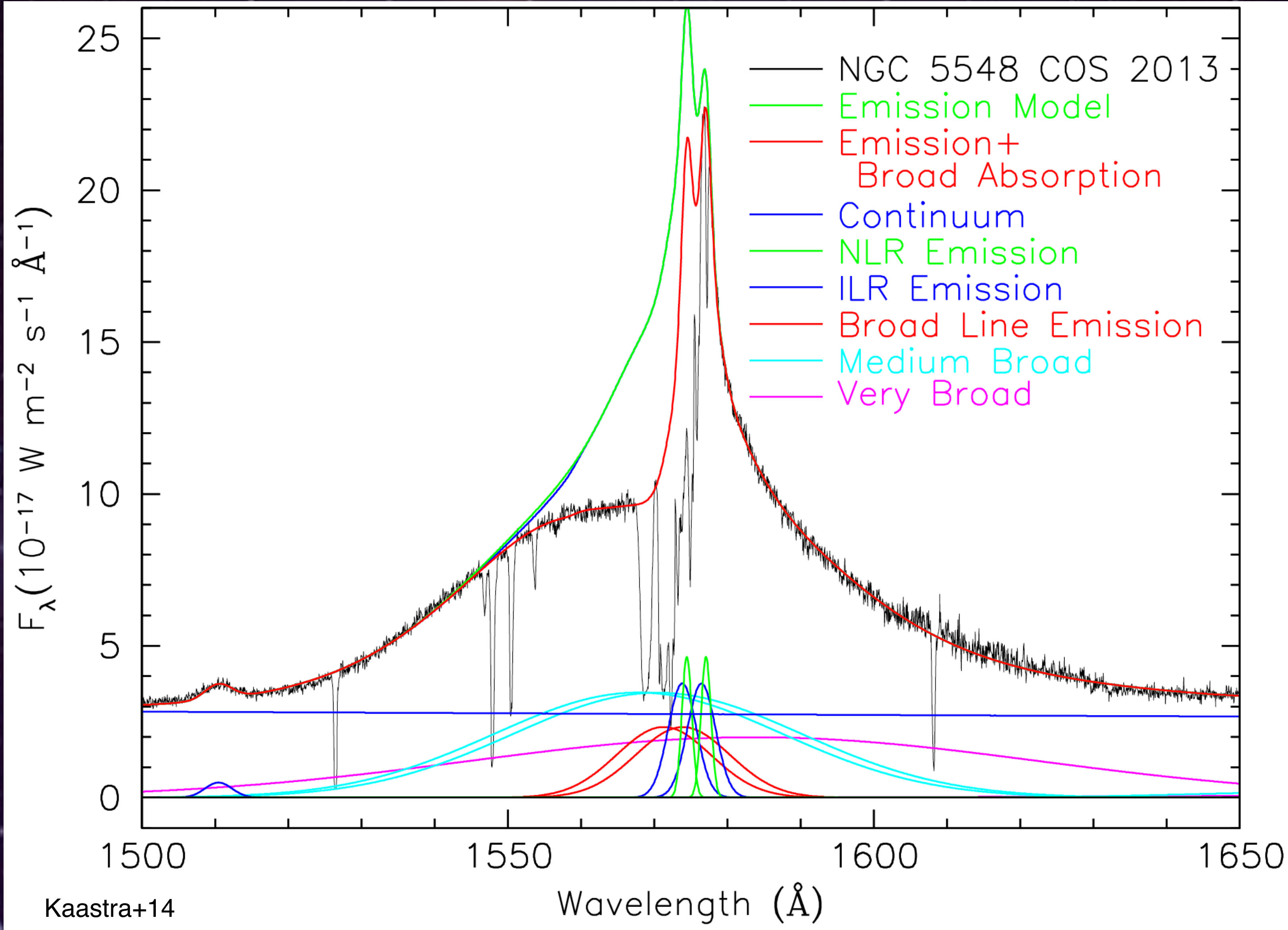


Changes in the X-ray Spectrum of NGC 5548



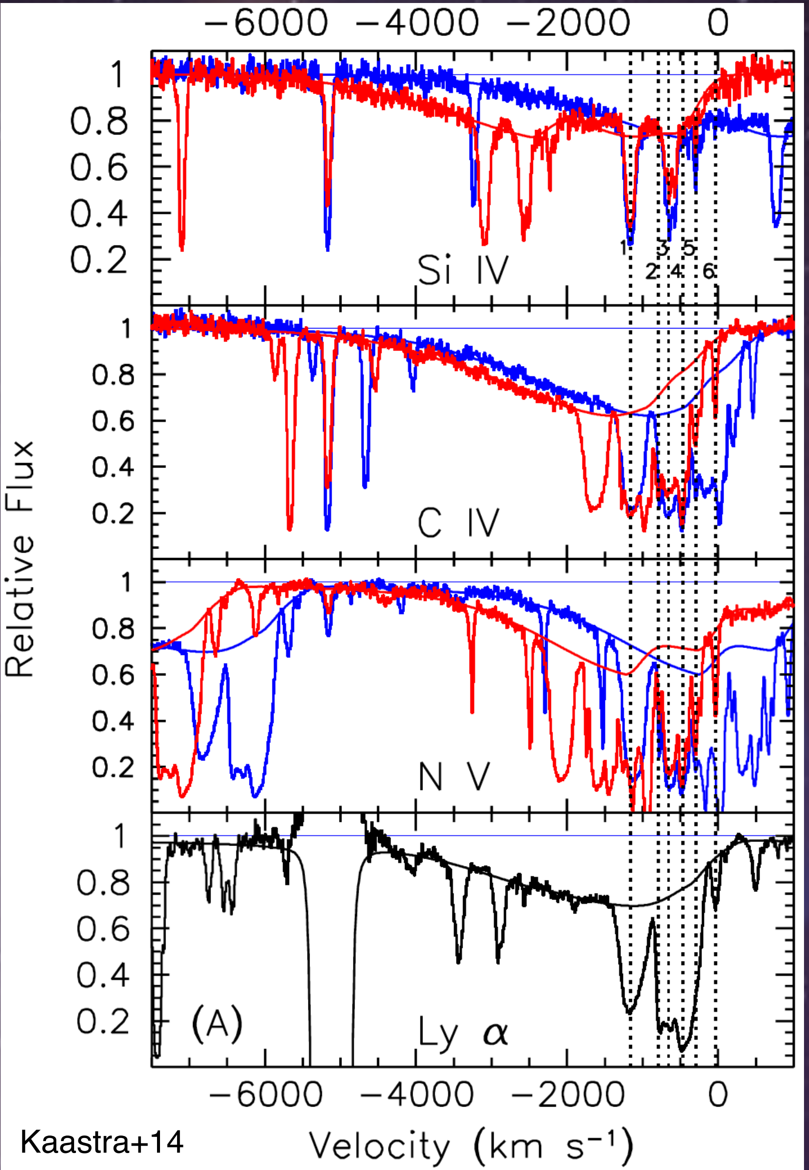
As of December 2016, Strong Soft X-ray Absorption is *Still* Obscuring NGC 5548

Broad C IV Absorption in NGC 5548



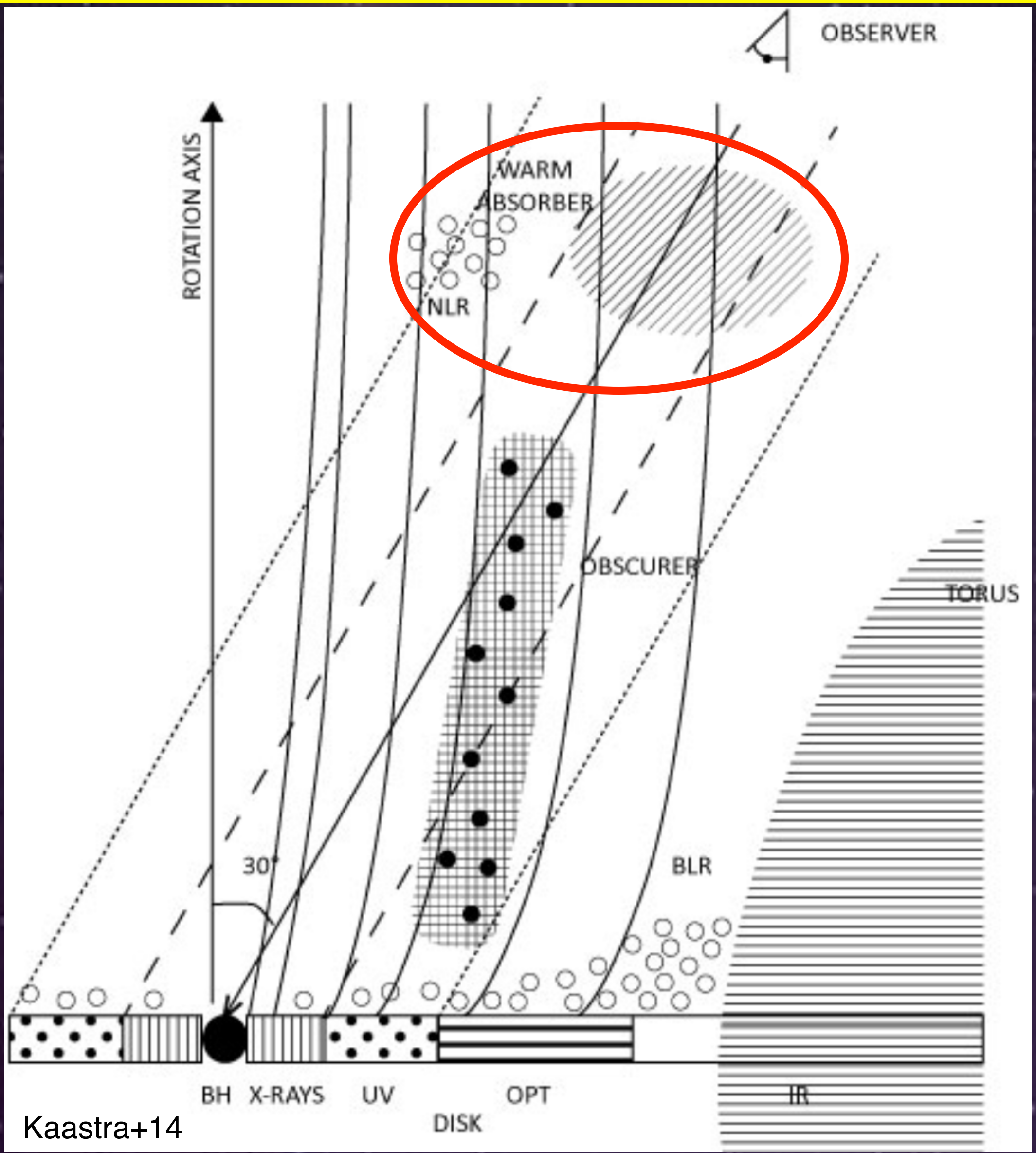
Kaastra+14

Normalized Broad Absorption Profiles in NGC 5548

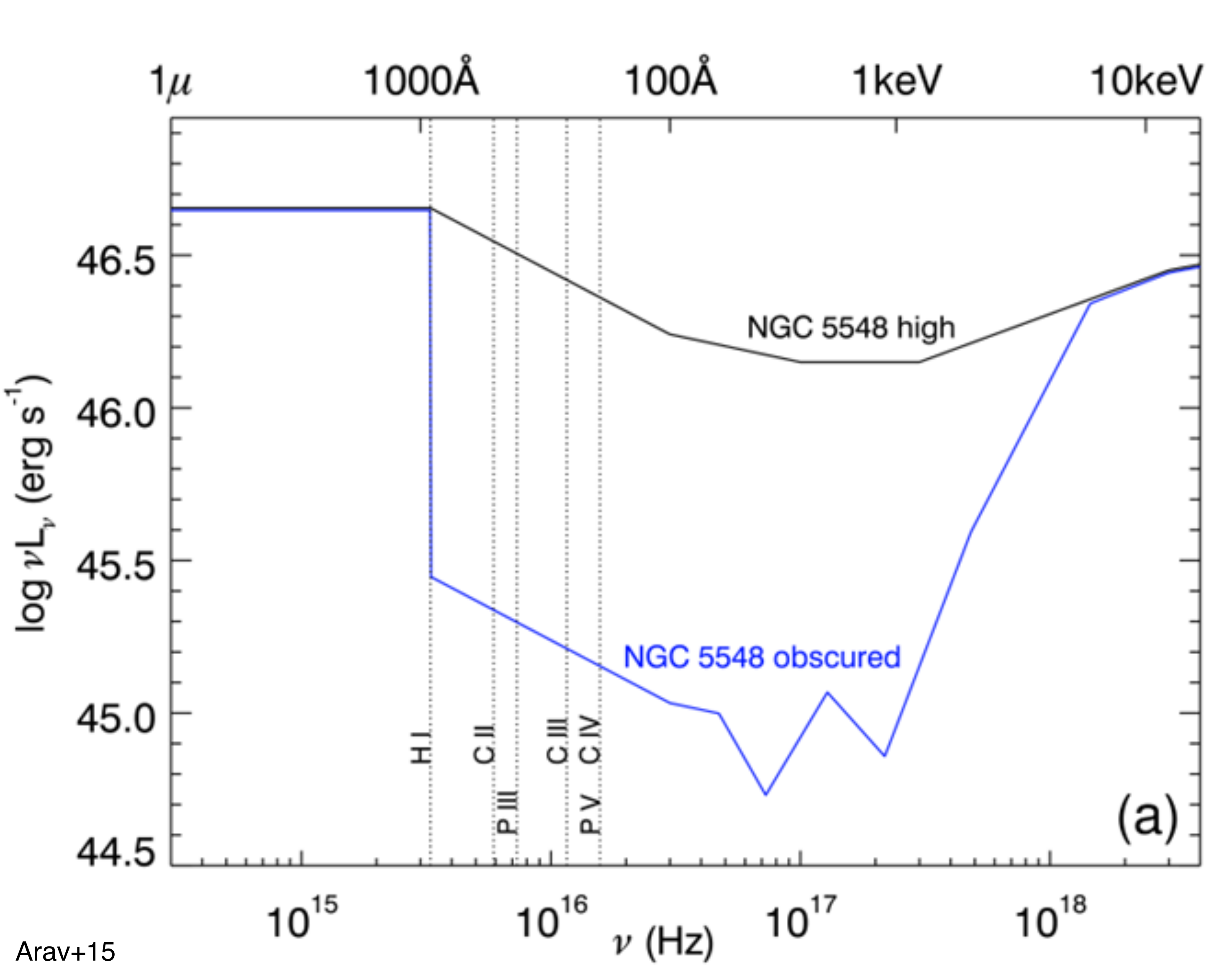


Kaastra+14

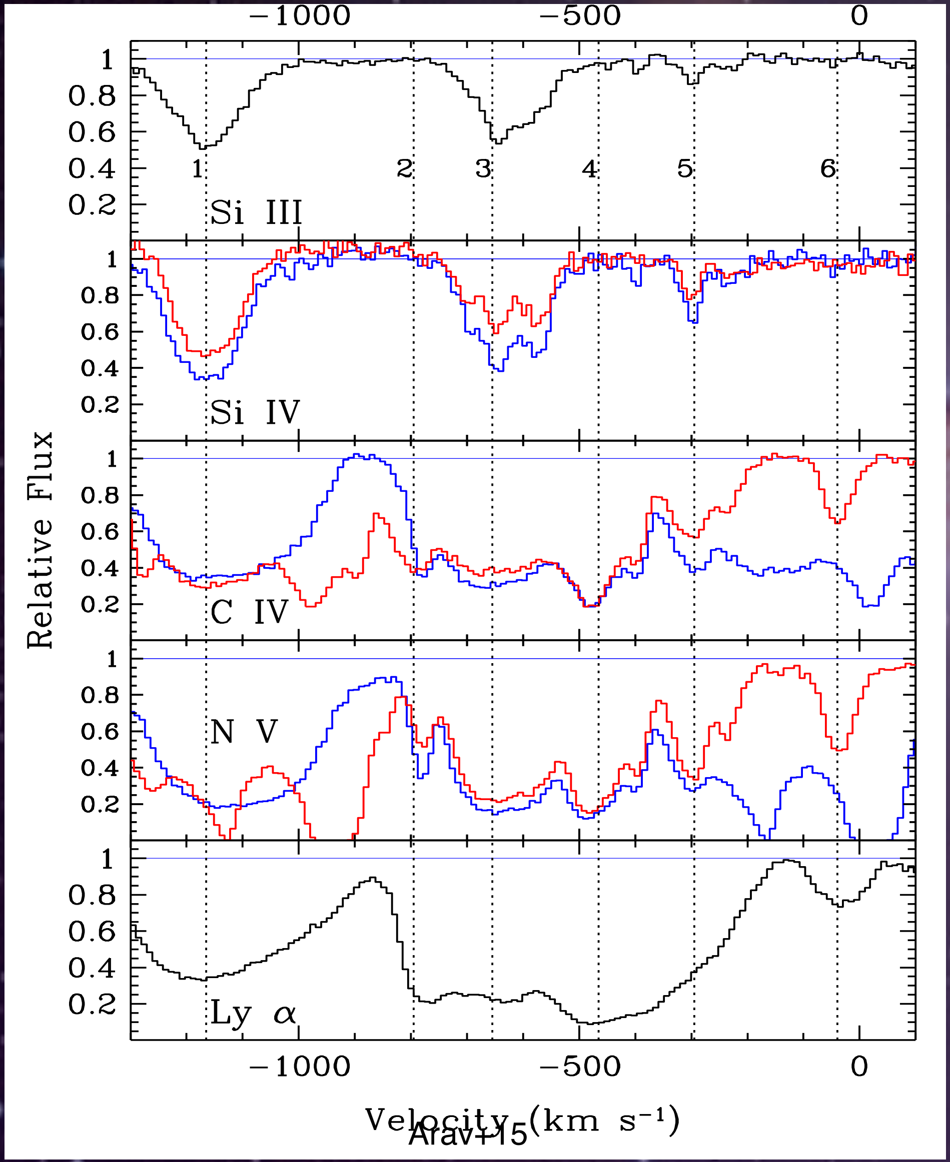
The Obscurer in NGC 5548 also Shadows the Warm Absorbers



The X-ray Obscurer also Obscures the UV-Ionizing part of the Spectral Energy Distribution

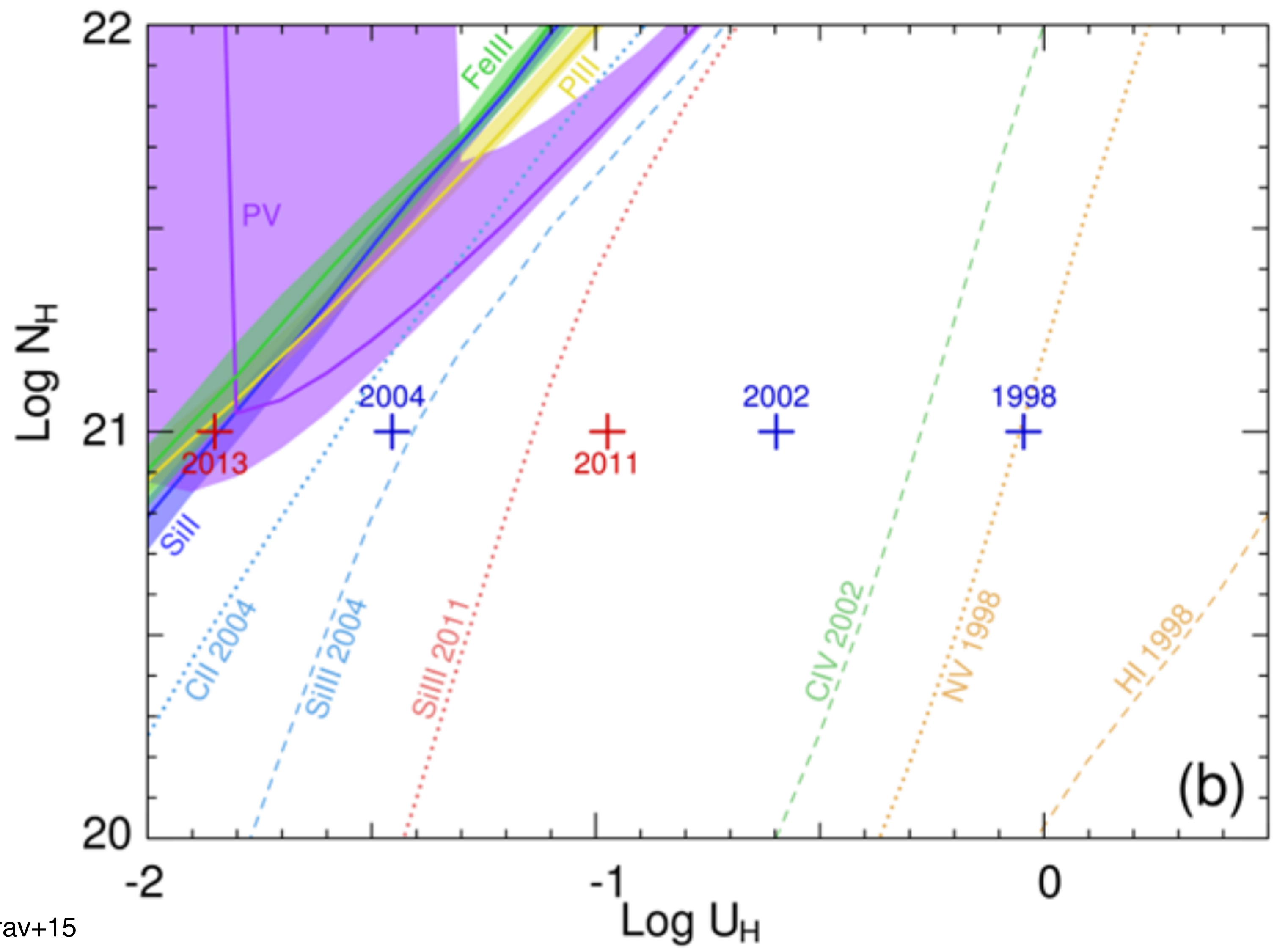


The Obscured Ionizing Continuum of NGC 5548 Reveals Low-ionization Narrow Absorption Lines

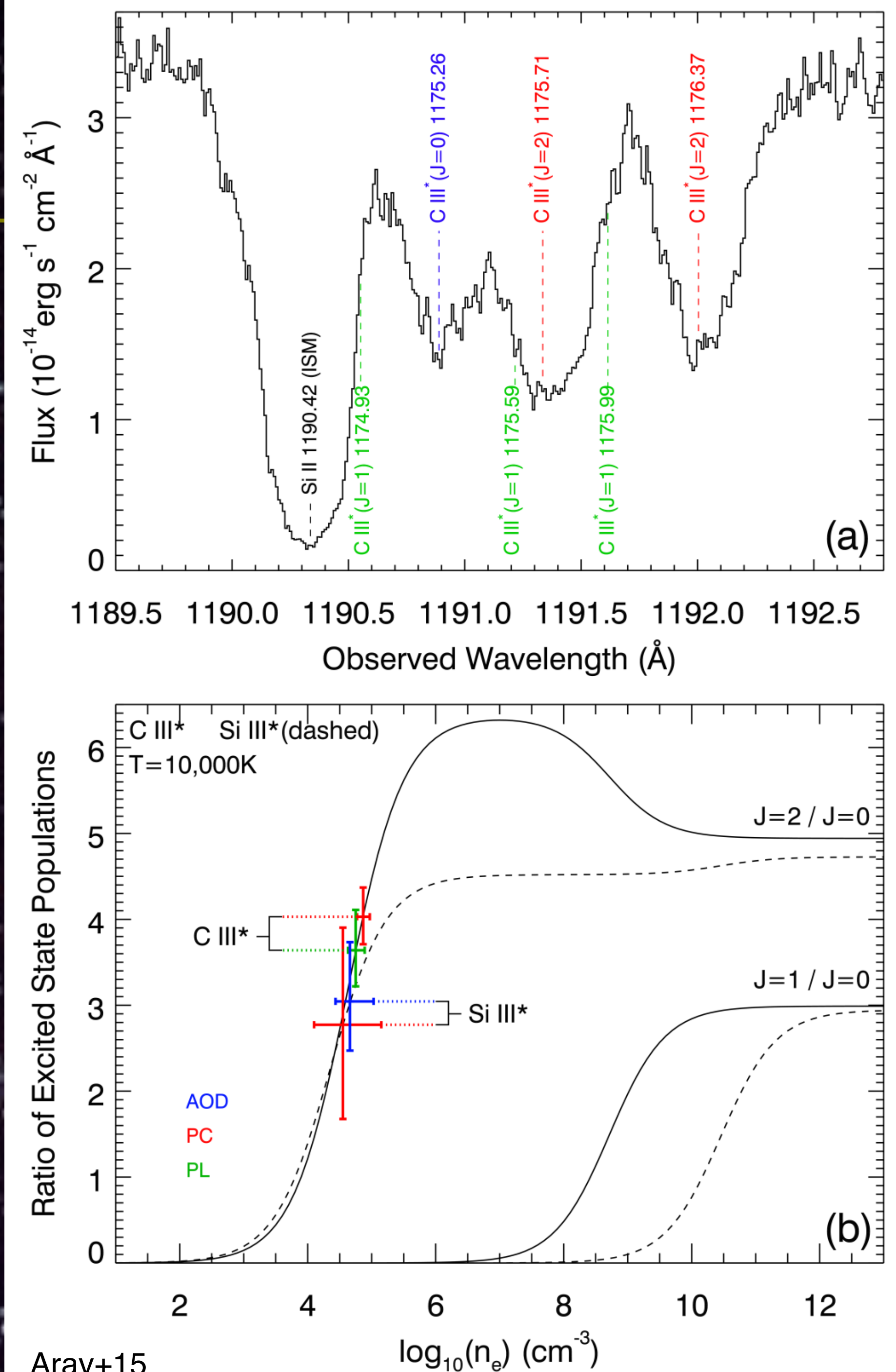


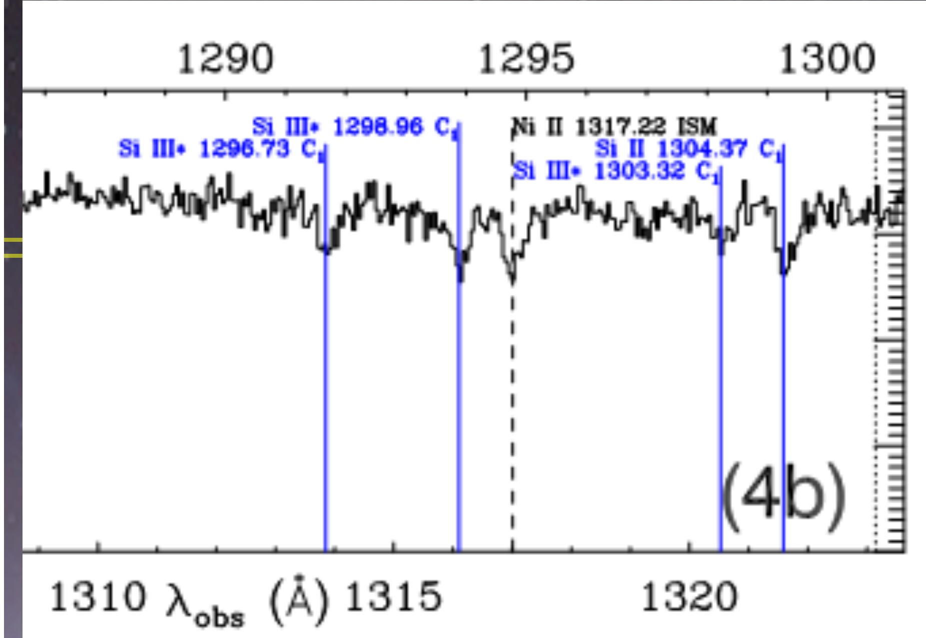
In addition to Si III, Si II, C III, C II, and PV absorption lines are also present in Component #1.

Photoionization Solutions for Component #1 (all 5 epochs)



Arav+15





- 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)

Using Recombination Times to Measure Density

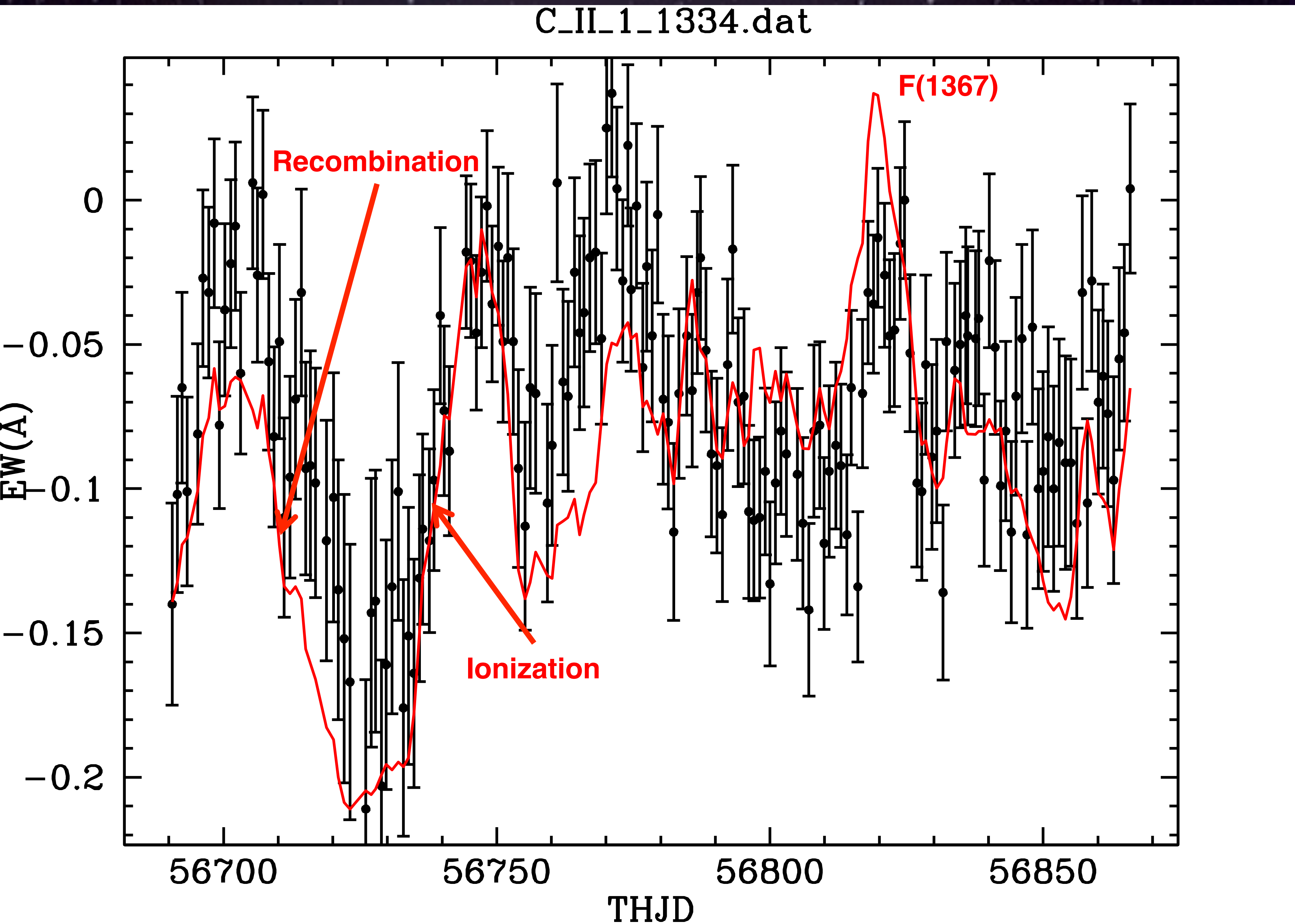
- Following Krolik & Kriss (1995), a simple model for time-dependent photoionization effects is given by

$$dn_i/dt = -(F_i\,\sigma_{ion,i} + n_e\alpha_{rec,i-1})n_i + n_e n_{i+1}\alpha_{rec,i} + F_{i-1}\,\sigma_{ion,i-1}n_{i-1}$$

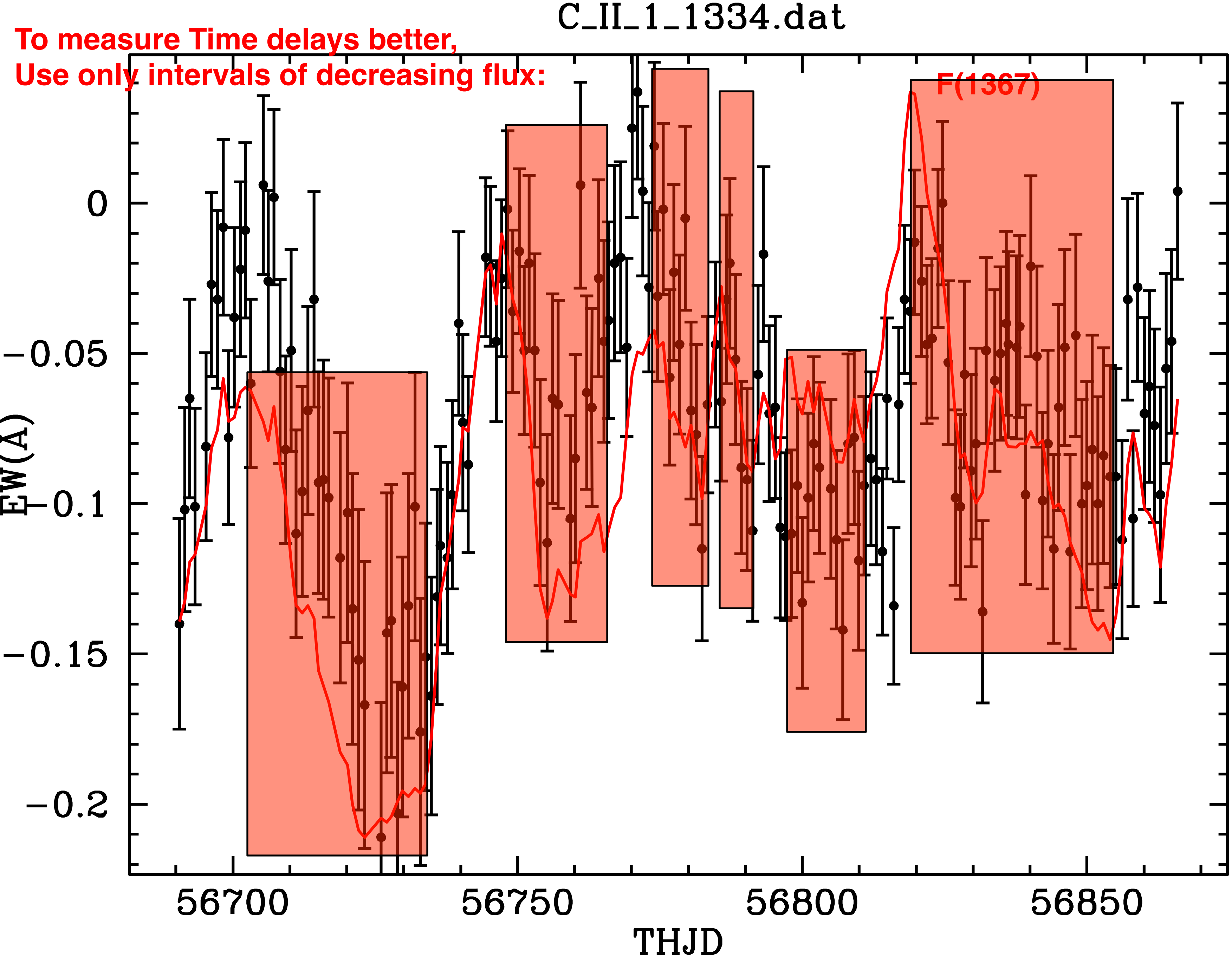
- For the ions we will be measuring, generally $n_{i-1} << n_i << n_{i+1}$, so

$$dn_i/dt = -F_i\,\sigma_{ion,i}\,n_i + n_e n_{i+1}\alpha_{rec,i}$$

- In general, as long as there is a copious increase in ionizing flux, the $-F_i\,\sigma_{ion,i}\,n_i b$ term dominates, and ions n_i are destroyed instantly. Conversely, when the flux decreases dramatically, $n_e n_{i+1}\alpha_{rec,i}$ dominates, and n_i reappears more slowly.


C_II_1_1334.dat
F(1367)
Recombination
Ionization
EW(Å)
0
−0.05
−0.1
−0.15
−0.2
56700
56750
56800
56850
THJD

To measure Time delays better,
Use only intervals of decreasing flux:



Atomic Physics Really Works!

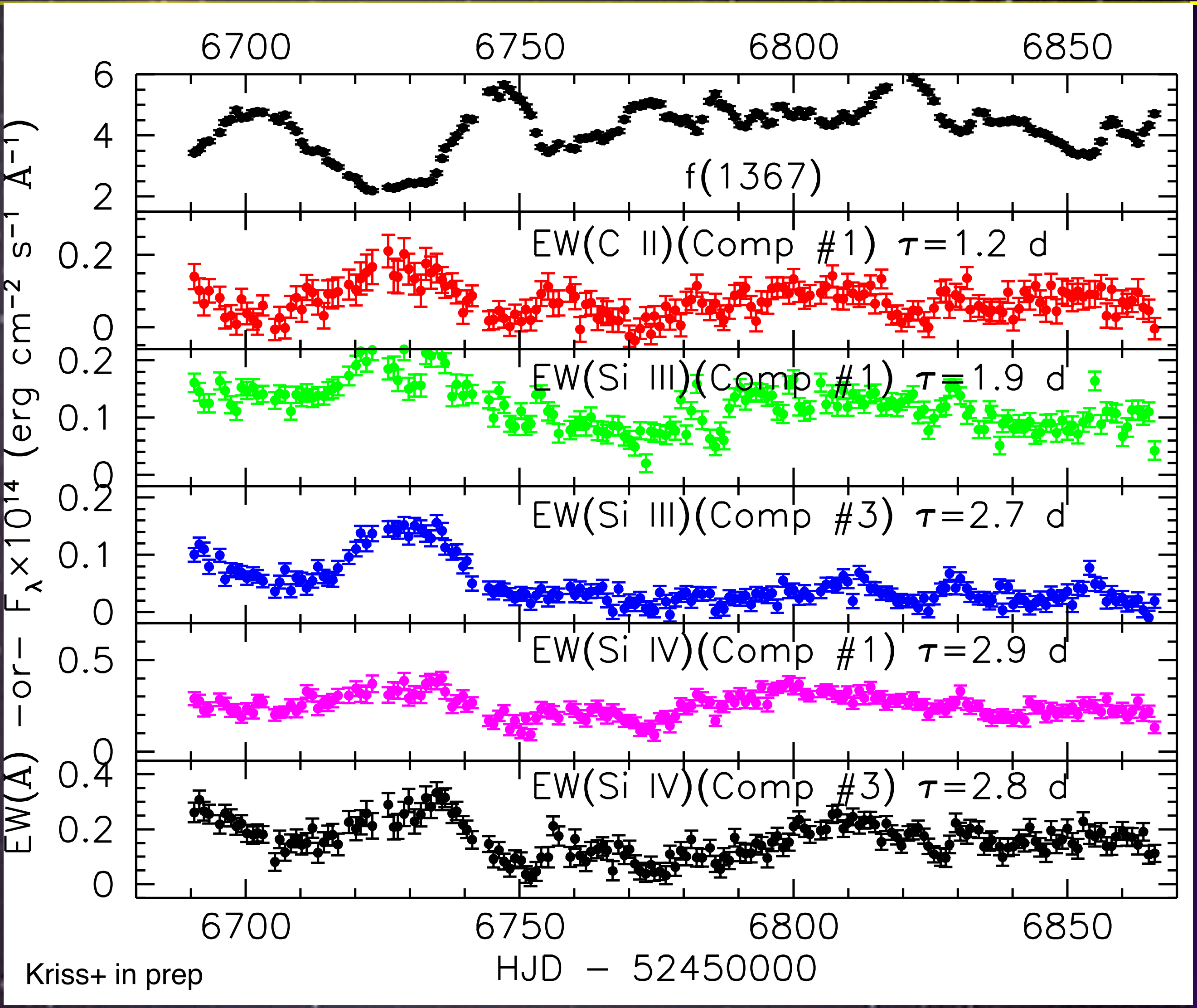
Ionization/recombination in the absorption lines smear and delay their response.

These time delays also give densities (log):

C II #1	5.0 ± 0.3 cm^{-3}
Si III #1	5.3 ± 0.3 cm^{-3}
Si IV #1	4.8 ± 0.2 cm^{-3}
Si III #3	5.1 ± 0.3 cm^{-3}
Si IV #3	4.8 ± 0.2 cm^{-3}

Densities are consistent with C III* and Si III* for Component #1.

Distances again are 3−5 pc, the same as the NLR of NGC 5548.



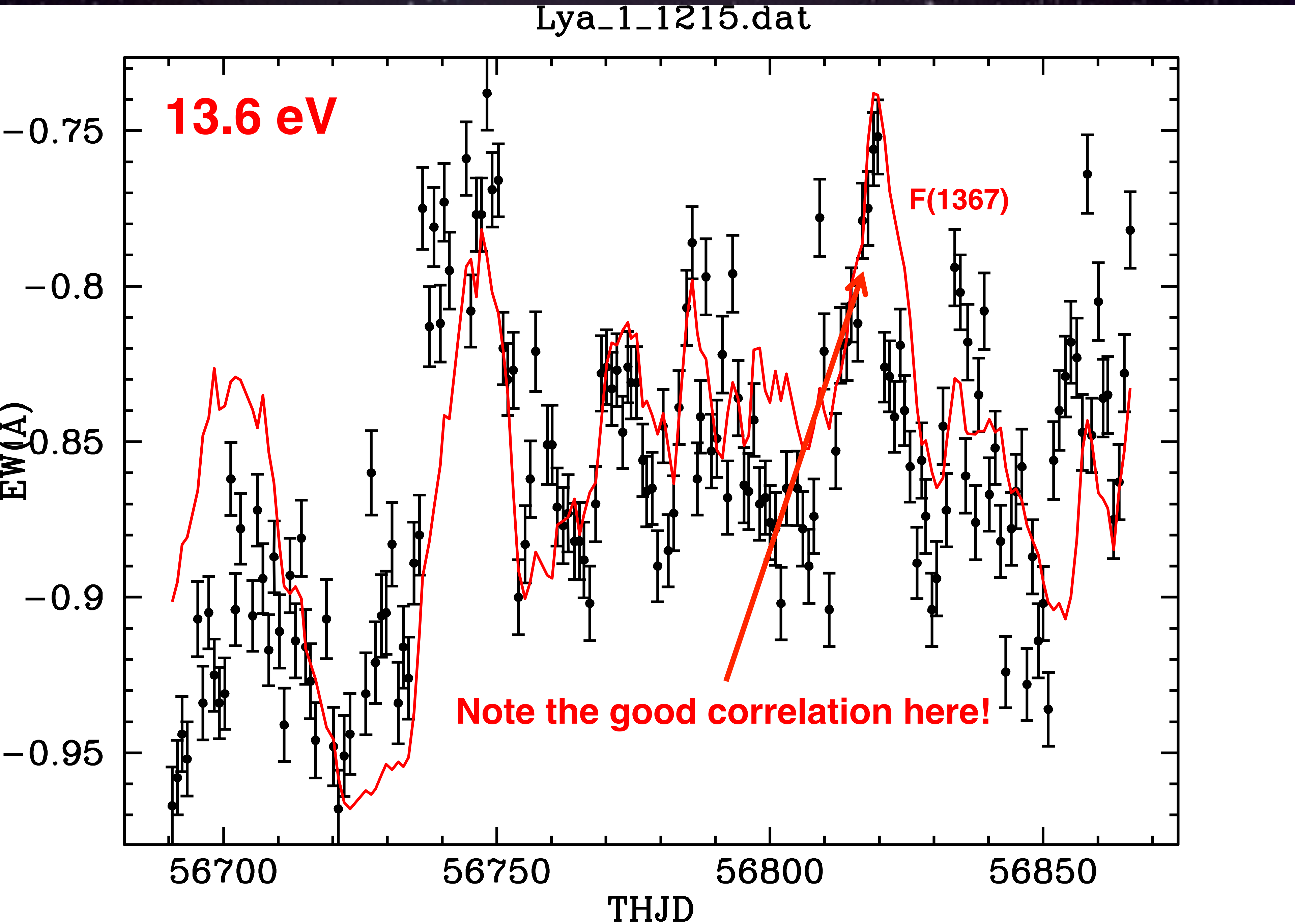
Possibilities for the BLR Holiday

a) Part of the BLR (a large part) is being shadowed by some structure that blocks the continuum to the BLR but not our line of sight.

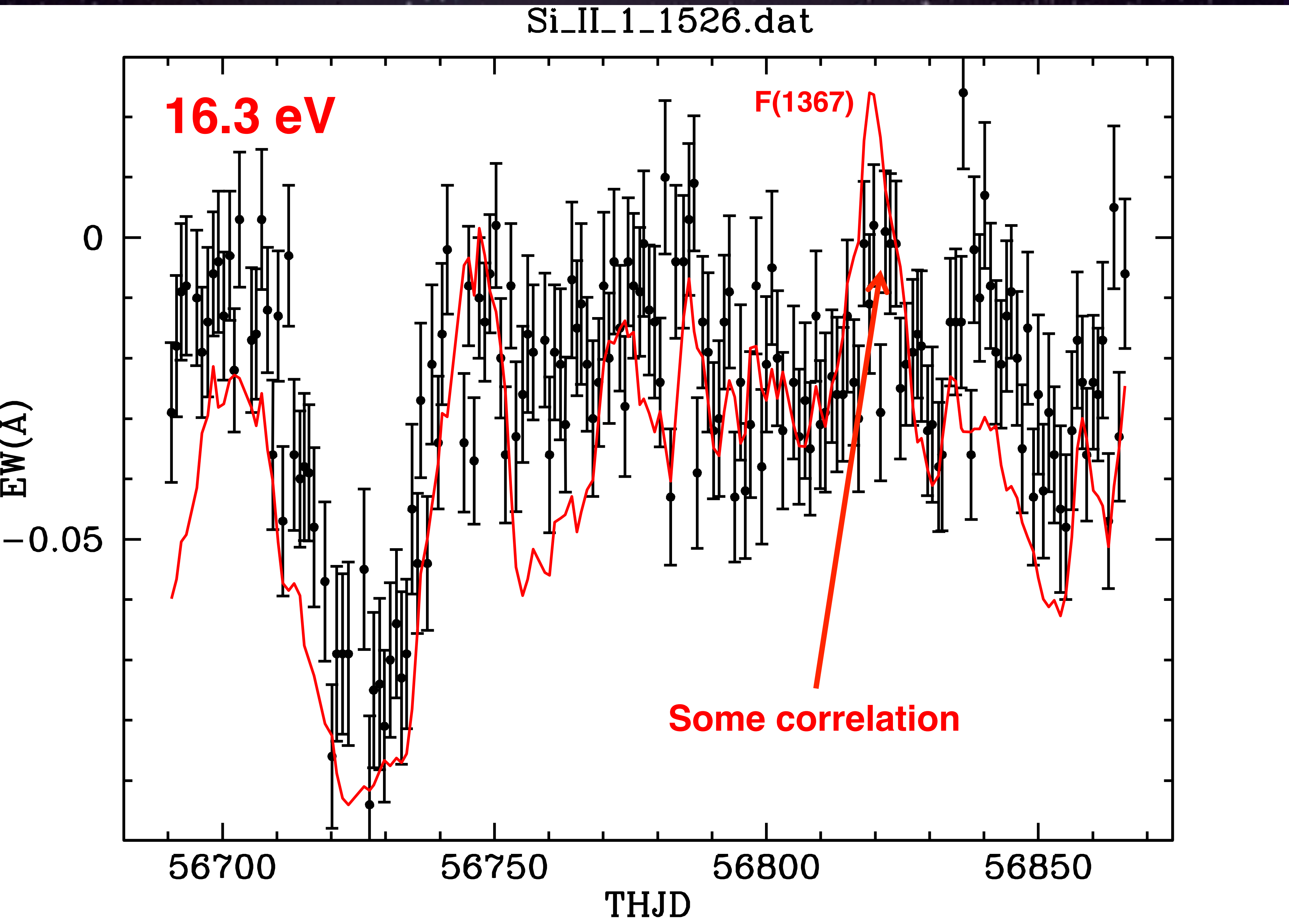
b) The continuum itself has changed, so that the SED has changed; given the depths of the decorrelation, it must be the high-energy portion of the ionizing continuum that has changed the most (e.g., He II decorrelates with the 1367 Å flux by 21%, Lyα by only 9%).

Peculiar responses of the Narrow Absorption Lines - Facts

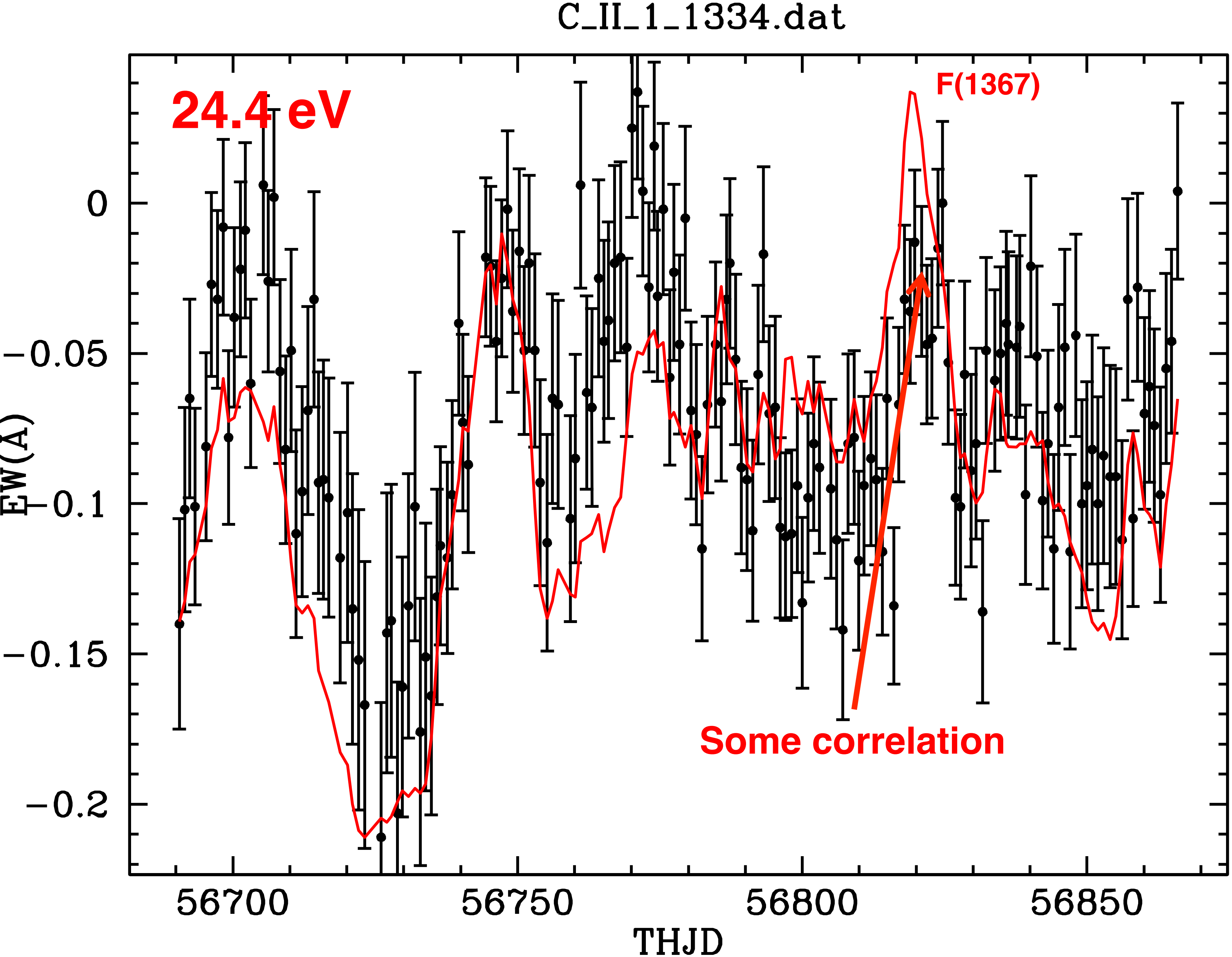
- The narrow absorption lines respond to continuum variations.
- Throughout the first two continuum peaks and troughs, the response is classic, textbook photoionization (instantaneous) and recombination (delayed, and density dependent).
- During the second half of the campaign, particularly throughout the BLR holiday, the absorption lines also decorrelate from the continuum. Peculiarly, some do not . . . C II λ1334, and Lyα . . .
- The following slides show light curves for narrow absorption by Component #1 ordered by increasing ionization potential: Lyα λ1216 (13.6 eV), Si II λ1526 (16.3 eV), C II λ1334 (24.4 eV), Si III λ1206 (33.5 eV), Si IV λ1393 and λ1402 (45.1 eV), C III* λ1775 (47.9 eV), C IV λ1548 (64.5 eV), and N V λ1238 (97.9 eV).



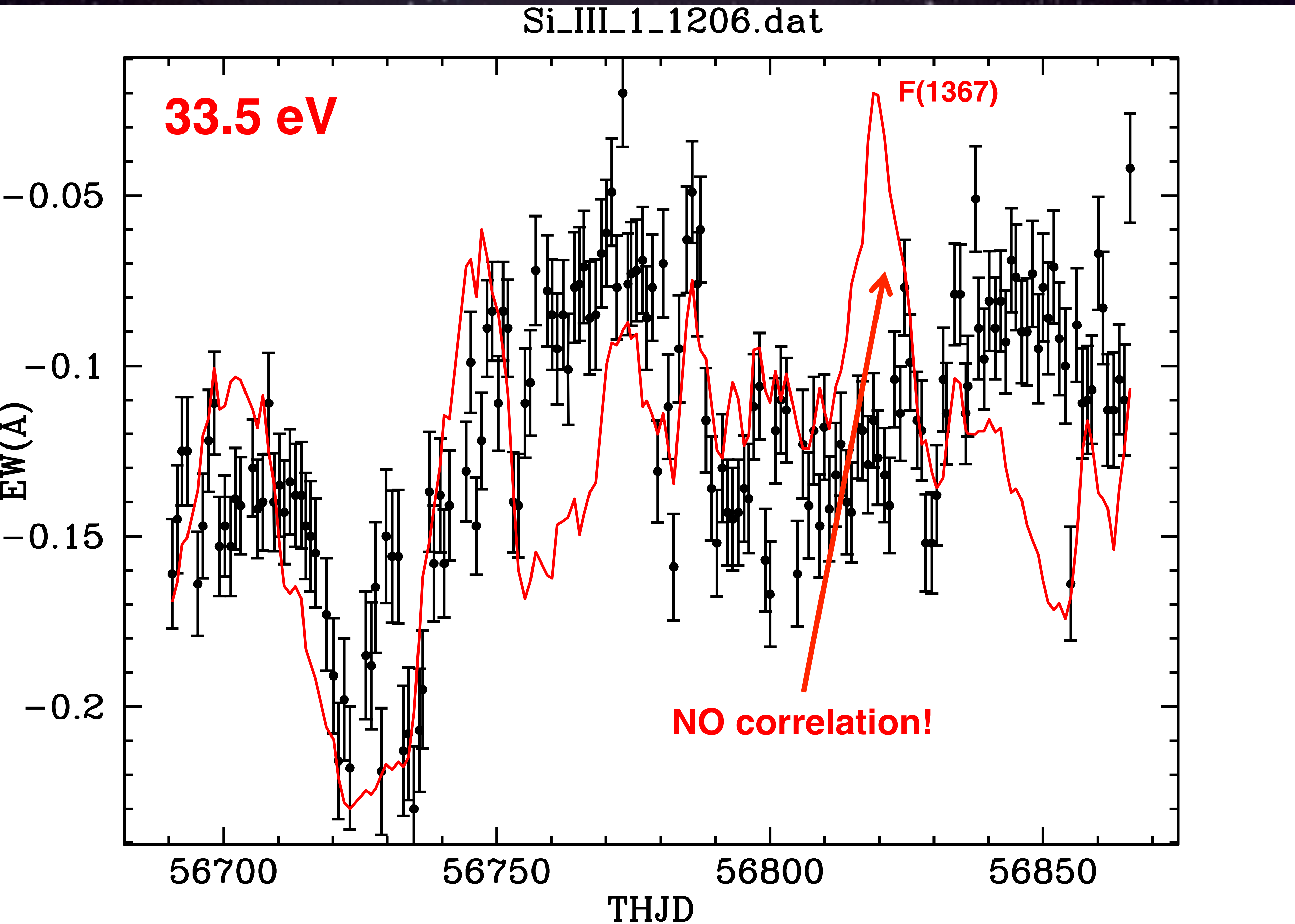
Lya_1_1215.dat
13.6 eV
F(1367)
Note the good correlation here!
EW(Å)
THJD
−0.75
−0.8
−0.85
−0.9
−0.95
56700
56750
56800
56850

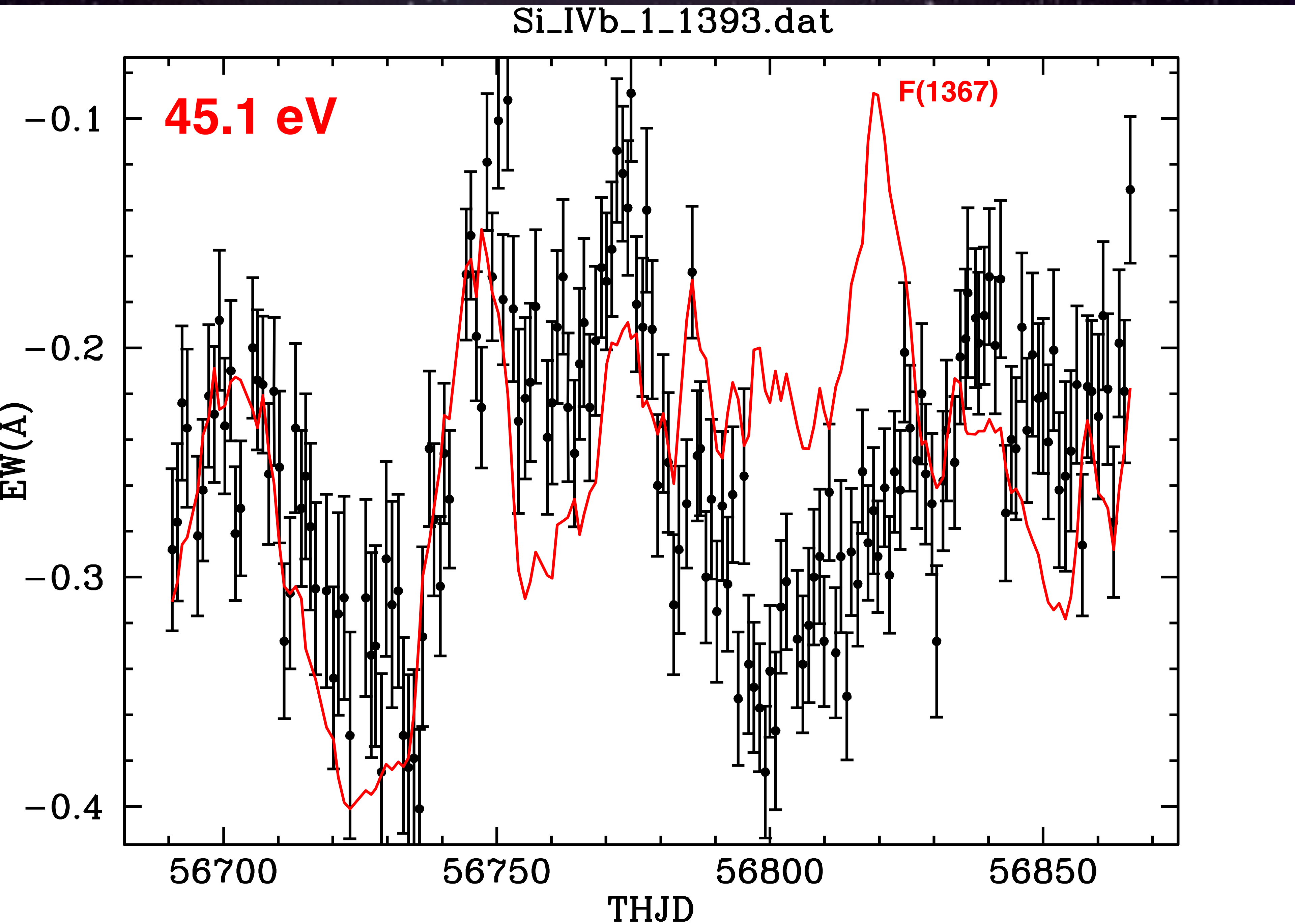


Si_II_1_1526.dat
16.3 eV
F(1367)
Some correlation
0
−0.05
EW(Å)
56700
56750
56800
56850
THJD

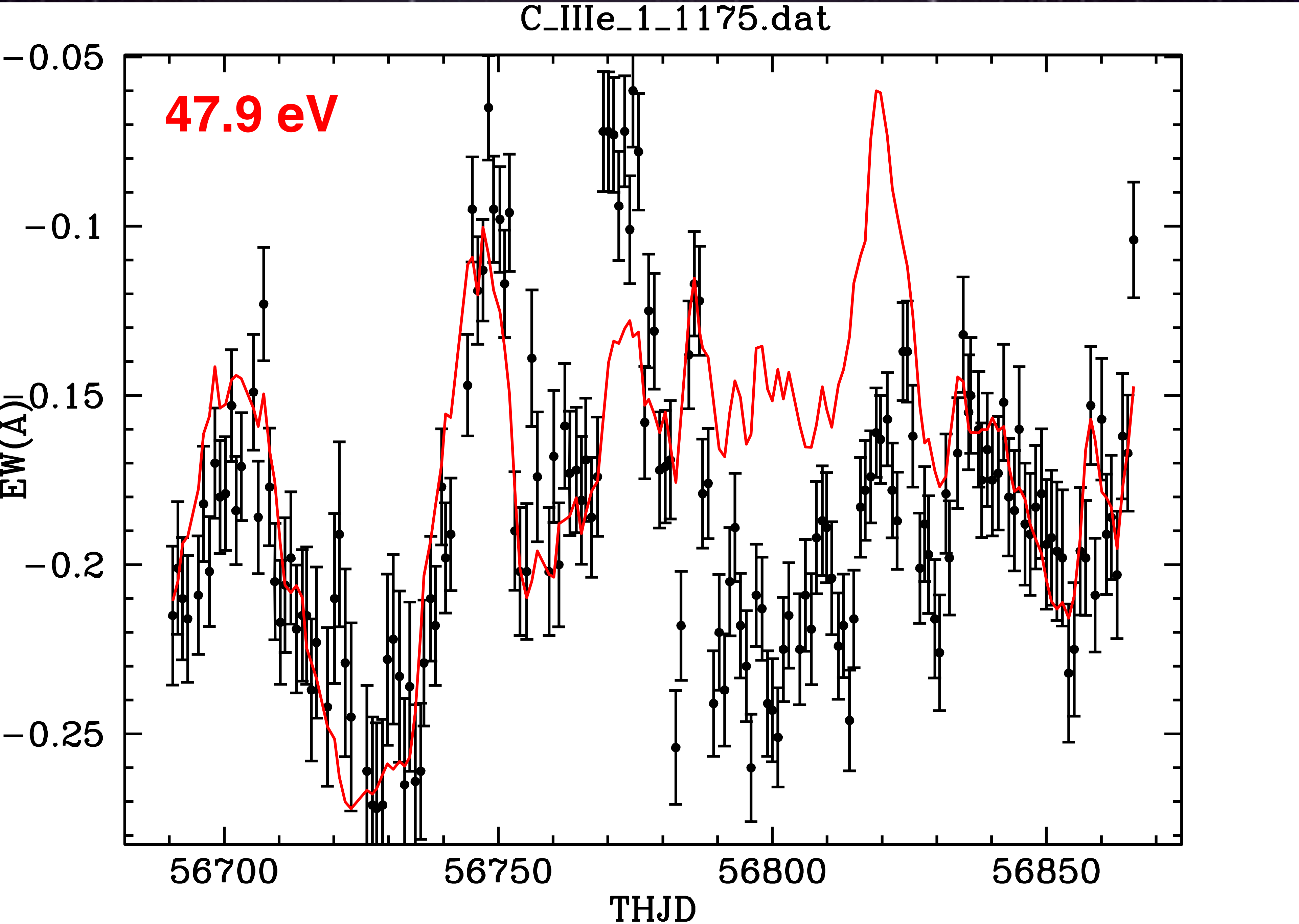


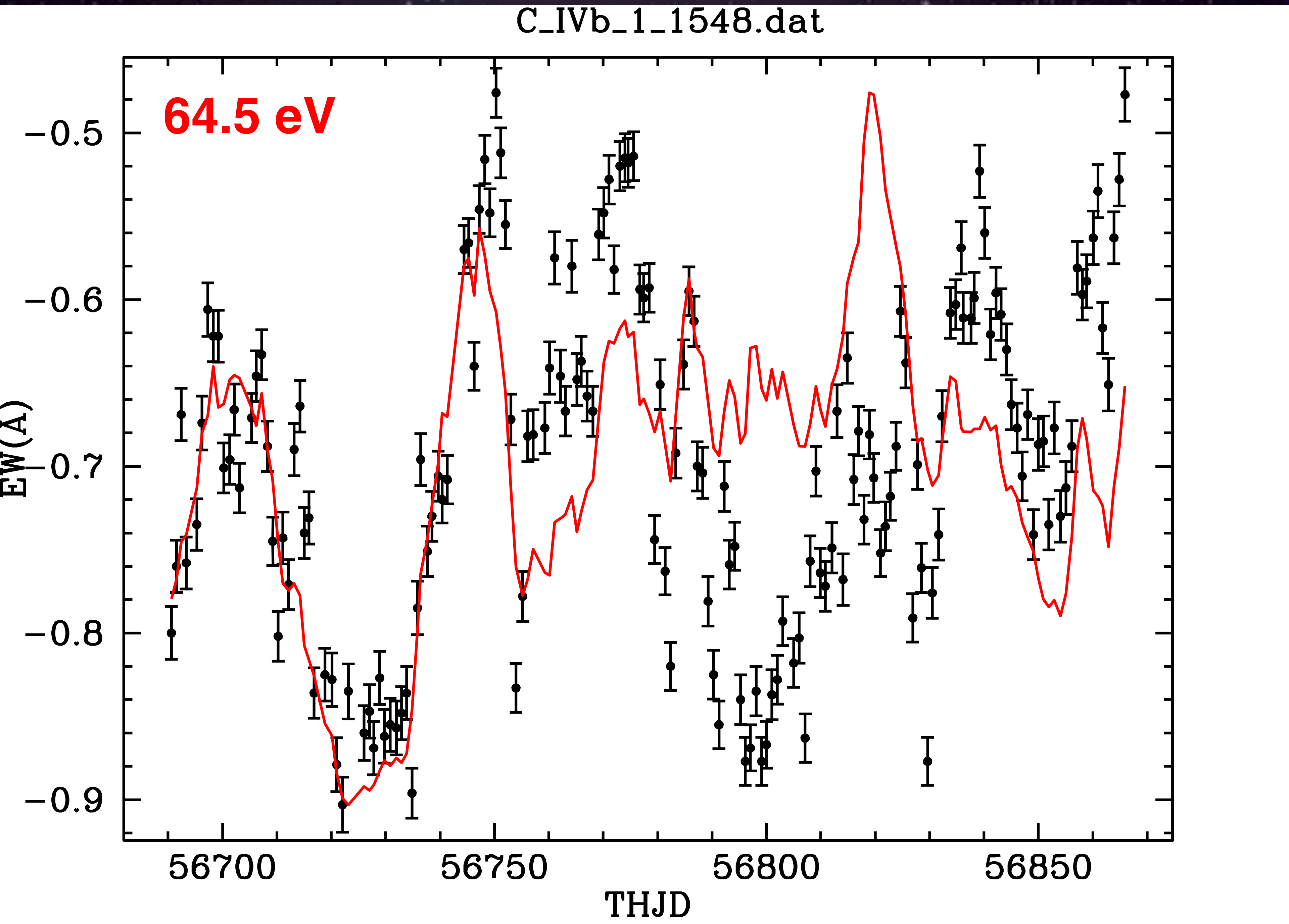
C_II_1_1334.dat
24.4 eV
F(1367)
Some correlation
0
−0.05
−0.1
−0.15
−0.2
EW(Å)
56700
56750
56800
56850
THJD


Si_III_1_1206.dat
33.5 eV
F(1367)
NO correlation!
EW(Å)
THJD
−0.05
−0.1
−0.15
−0.2
56700
56750
56800
56850

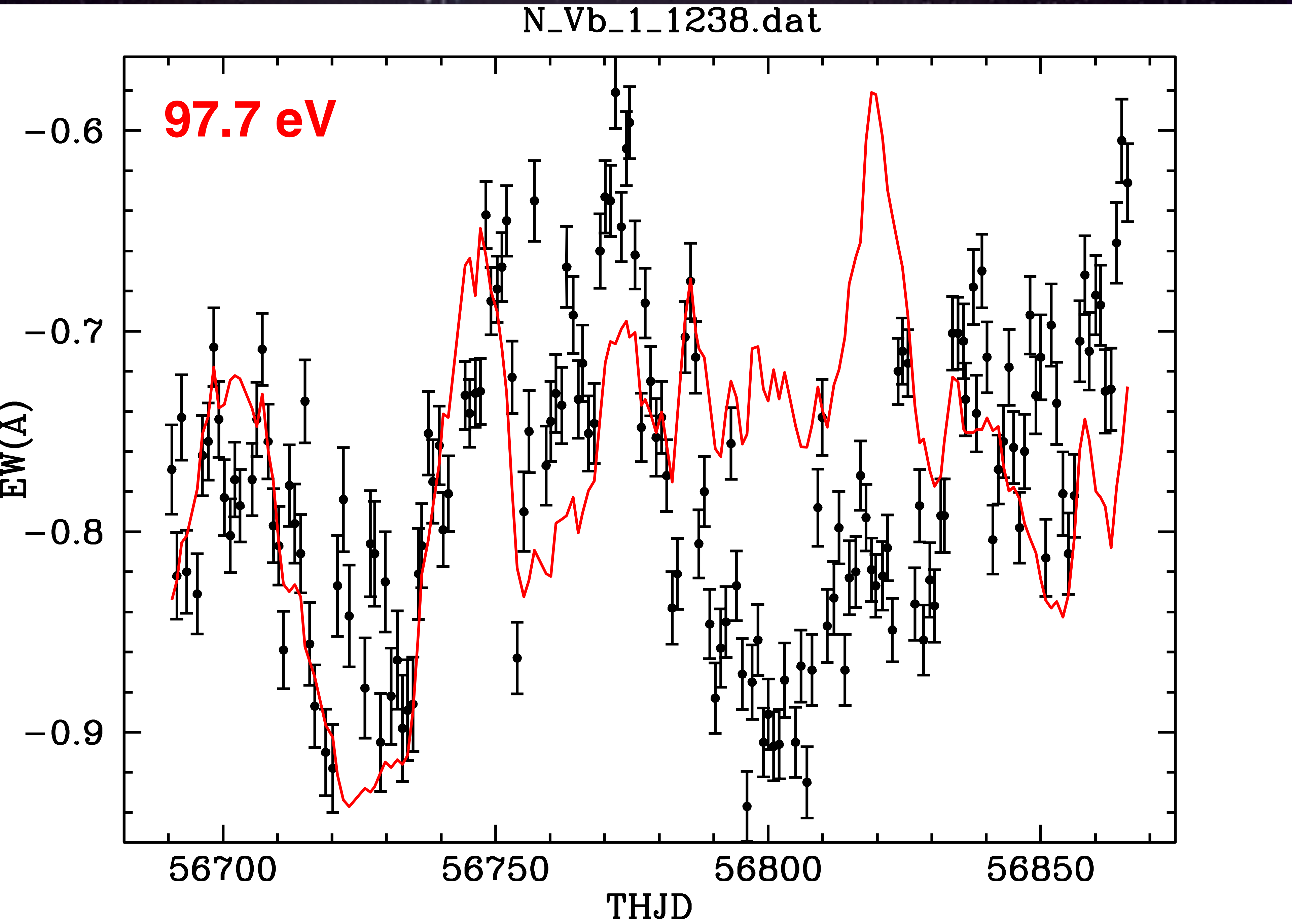


Si_IVb_1_1393.dat
45.1 eV
F(1367)
−0.1
−0.2
−0.3
−0.4
EW(Å)
56700
56750
56800
56850
THJD


C_IIIe_1_1175.dat
47.9 eV
−0.05
−0.1
−0.15
−0.2
−0.25
EW(Å)
56700
56750
56800
56850
THJD

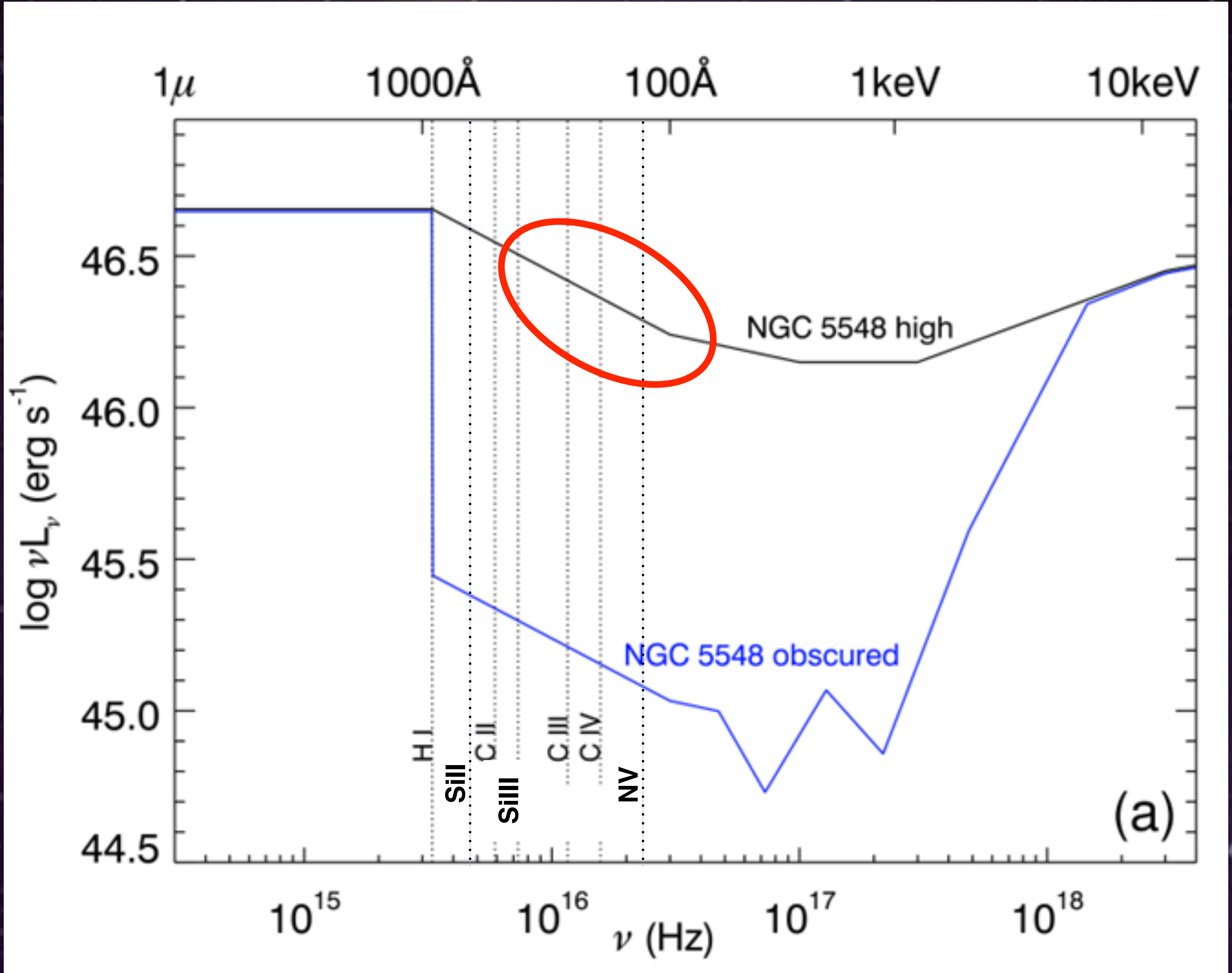


C_IVb_1_1548.dat
64.5 eV
−0.5
−0.6
−0.7
−0.8
−0.9
EW(Å)
56700
56750
56800
56850
THJD

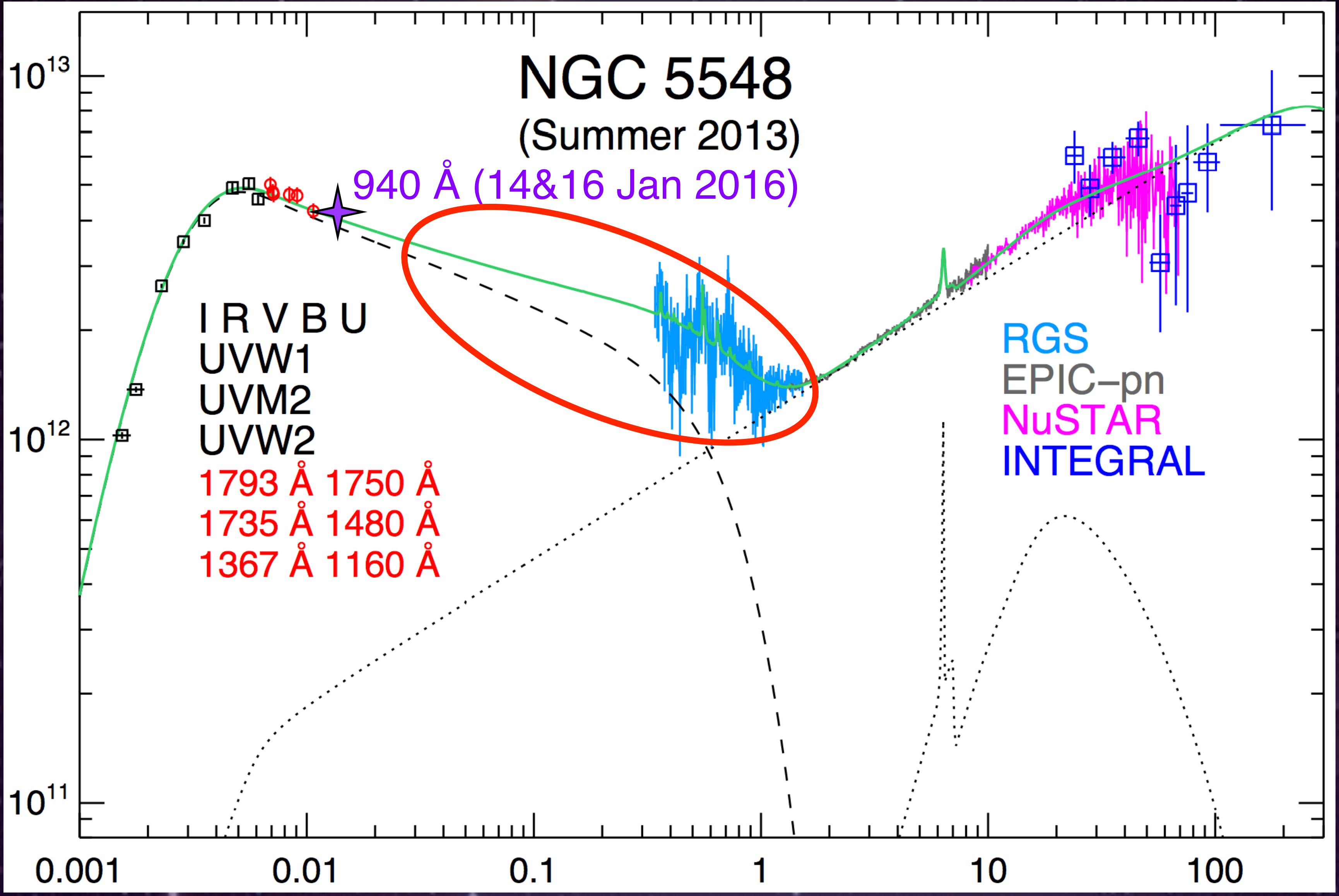


N_Vb_1_1238.dat
97.7 eV
EW(Å)
−0.6
−0.7
−0.8
−0.9
56700
56750
56800
56850
THJD

This change must be affecting the ionizing continuum at energies >~30 eV.



- This change would affect the high-energy tail of the warm, Comptonized inner region of the disk
- Is it a change in the intrinsic flux, or a change in the obscurer?

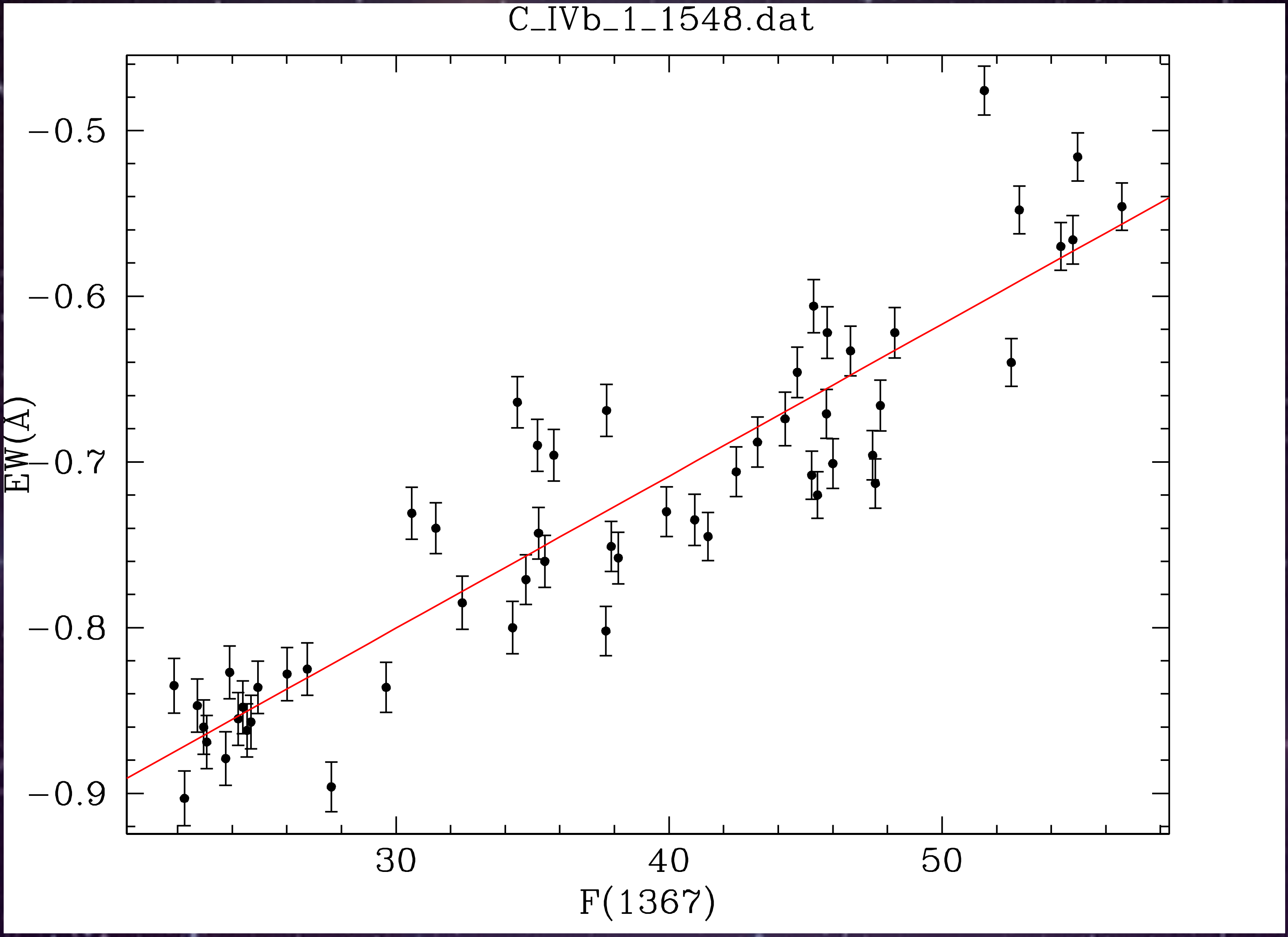


Inferring the SED in the Extreme Ultraviolet

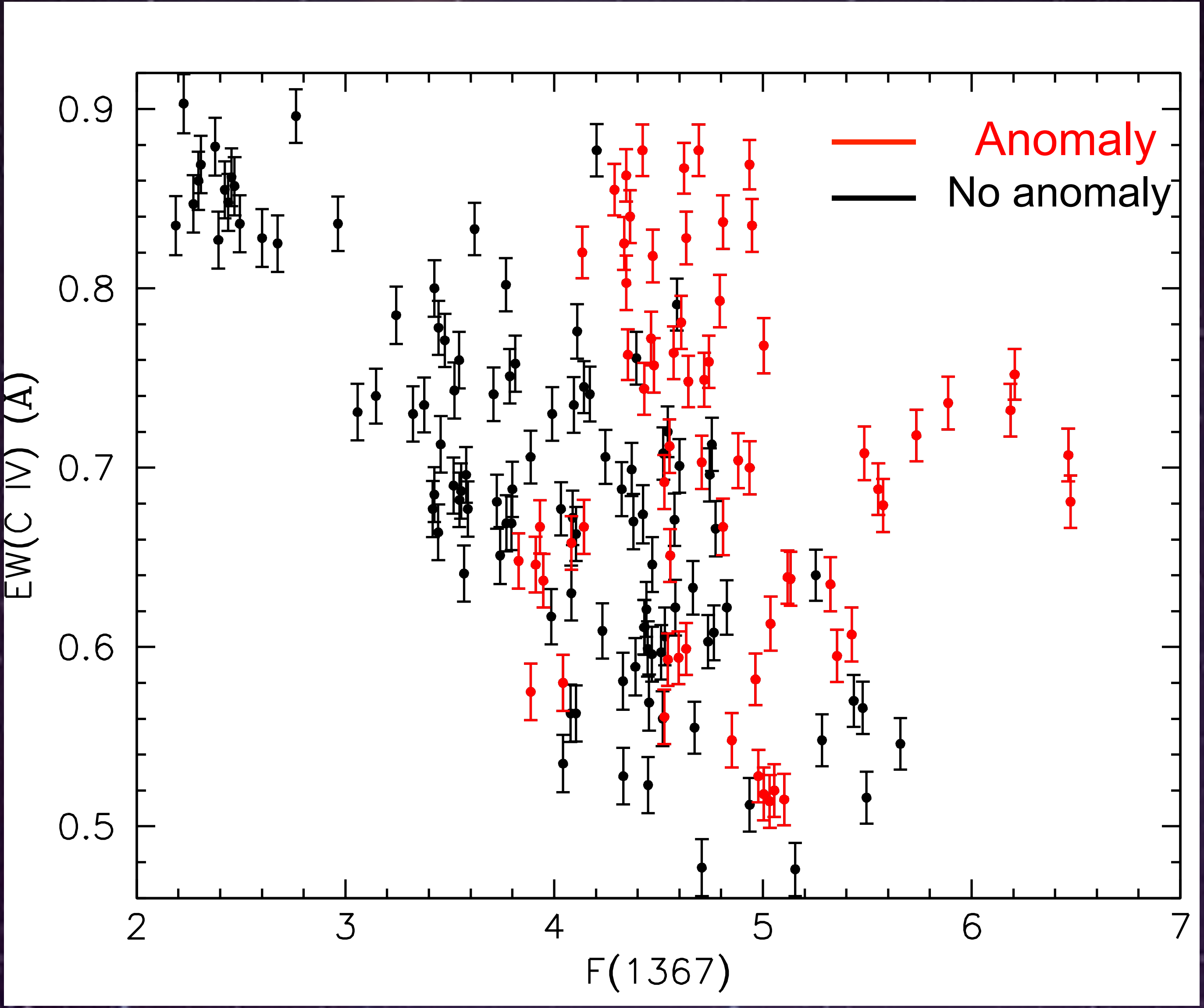
- As Gary Ferland noted last summer, "The absorption lines are the key. They're along the line of sight, and they see the same continuum."
- Take Gary at his word. To a good first approximation, the ionizing flux at a line's ionization potential *IS* the ionizing flux driving that line (or, is at least directly proportional to it).
- For the first 55 days of the campaign, this ionizing flux is well tracked by the far-UV continuum flux at 1367 Å seen by HST.
- For each line, use this proportionality to derive a relationship between a line's EW and the continuum flux:

$$EW = a0 + a1 * F1367$$

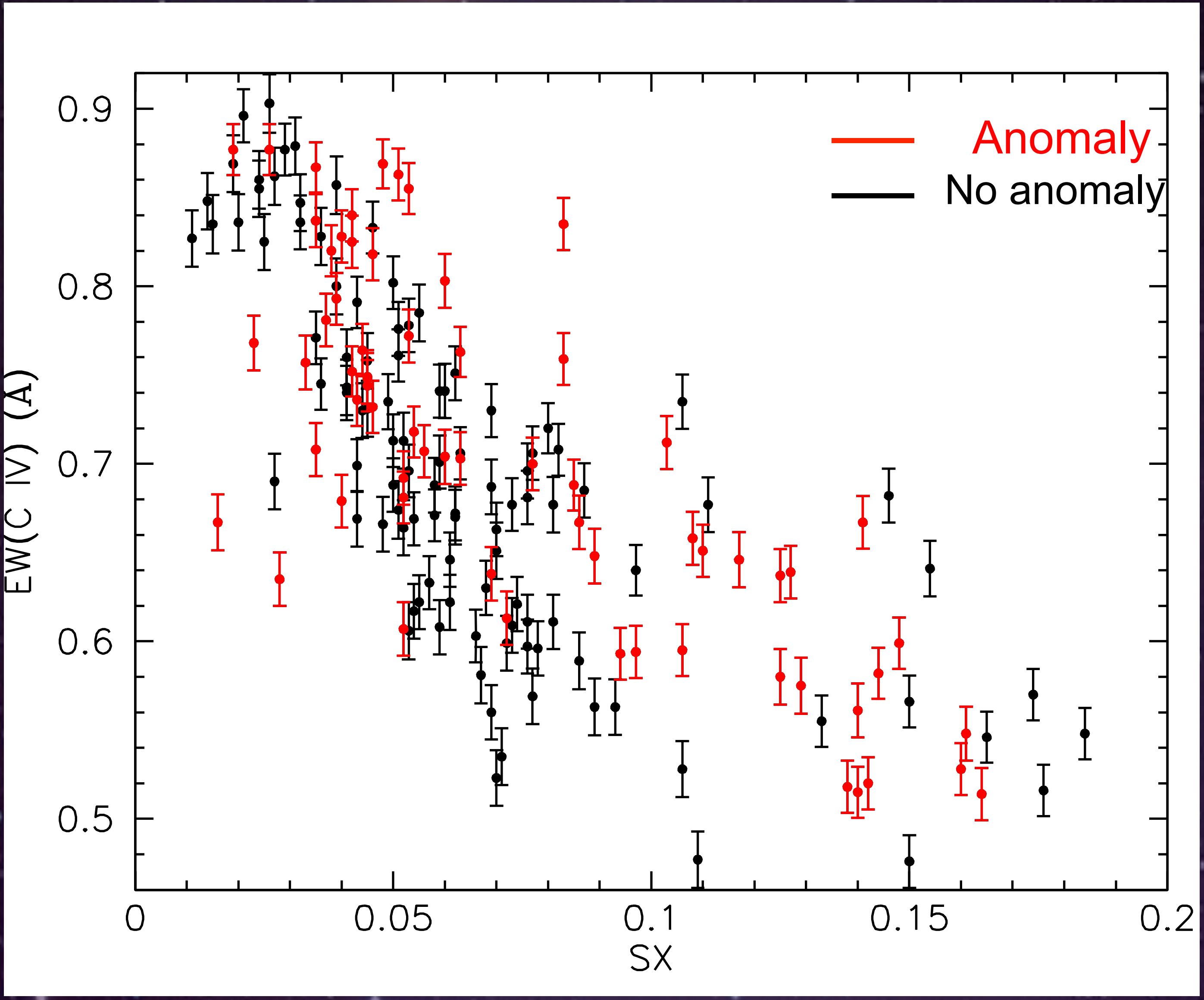
Good Correlation for C IV for the First 55 Days



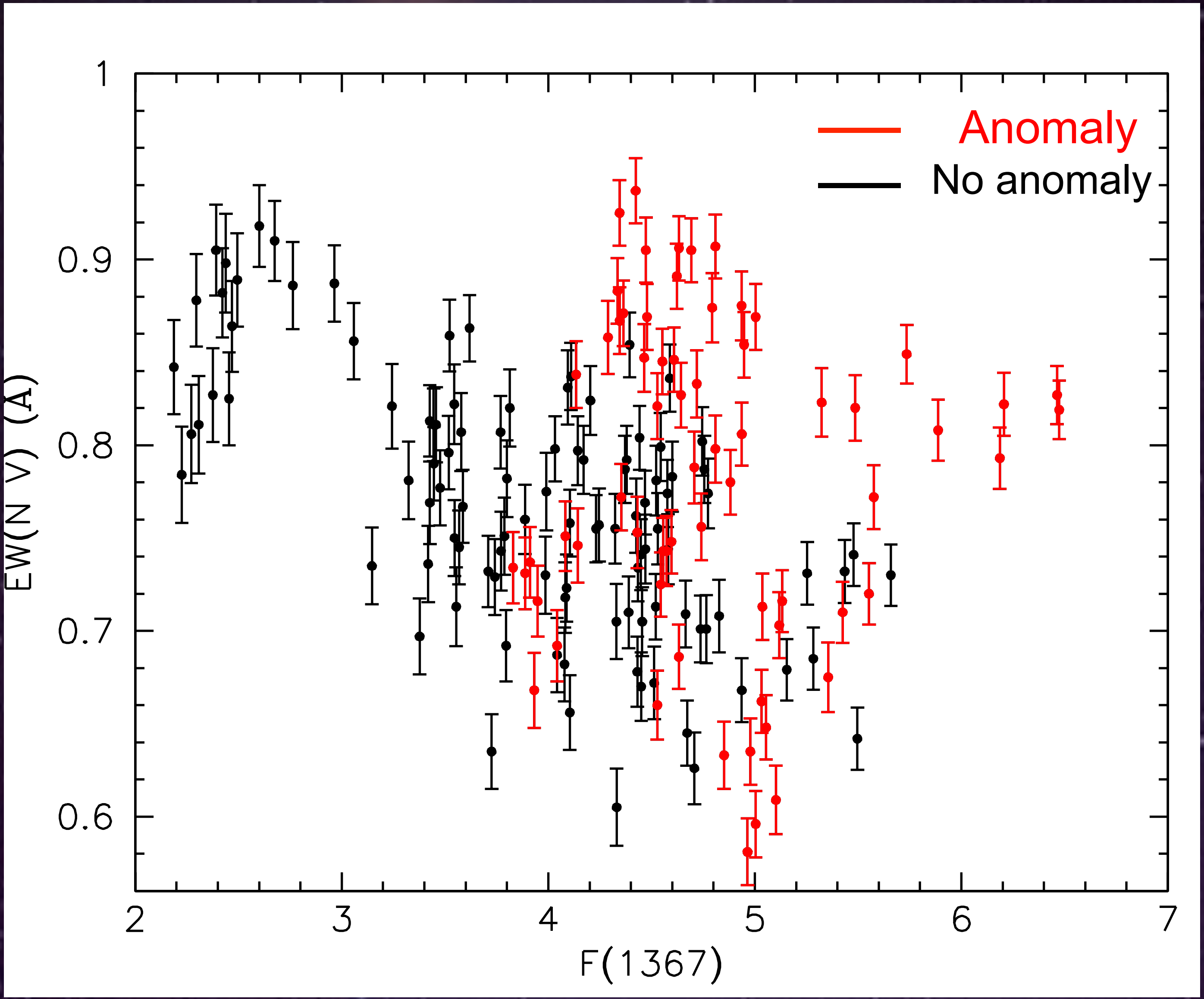
Poor Correlation between EW and F(1367) in C IV for the Full Campaign



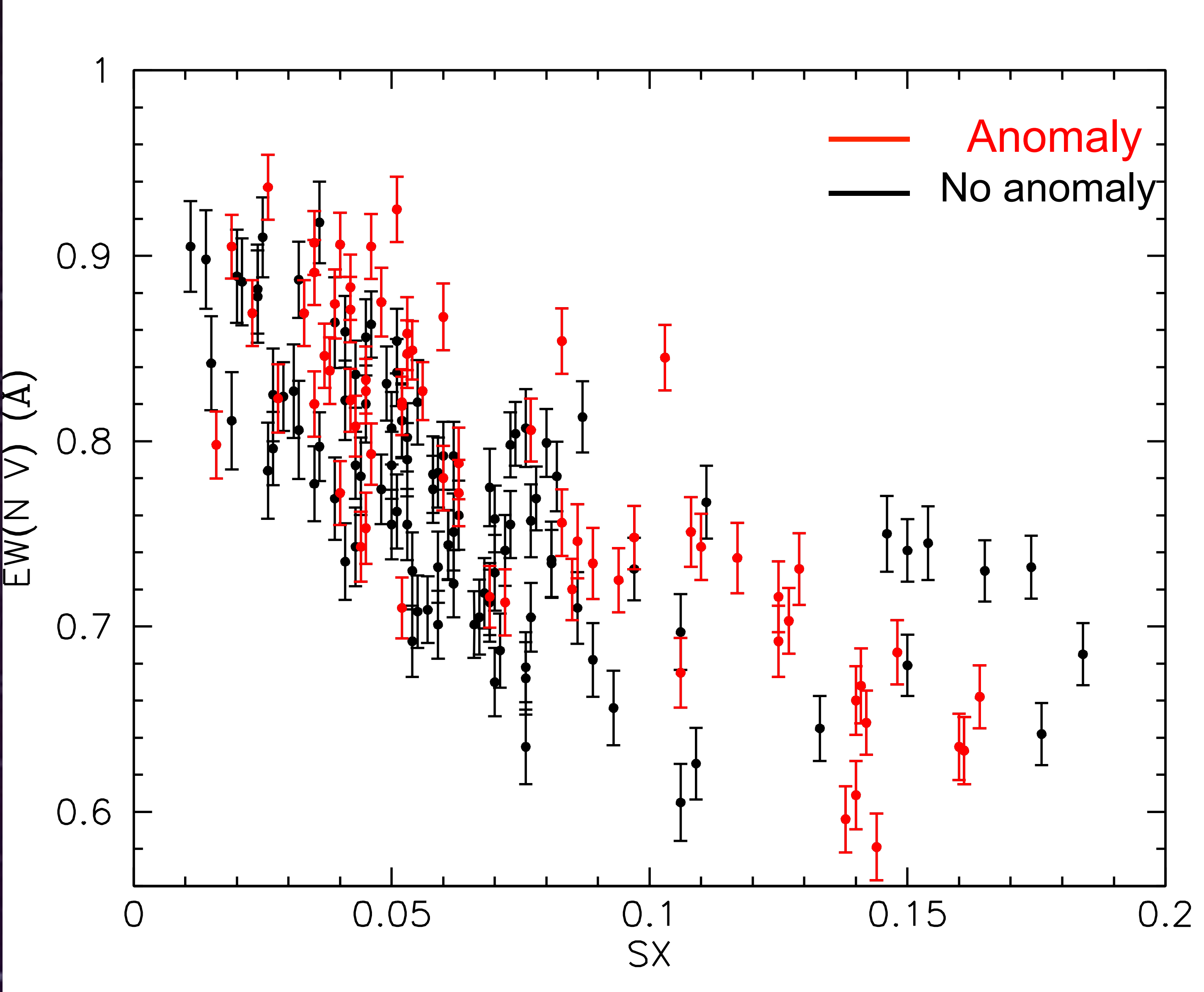
Better Correlation of CIV with the Soft X-ray Flux



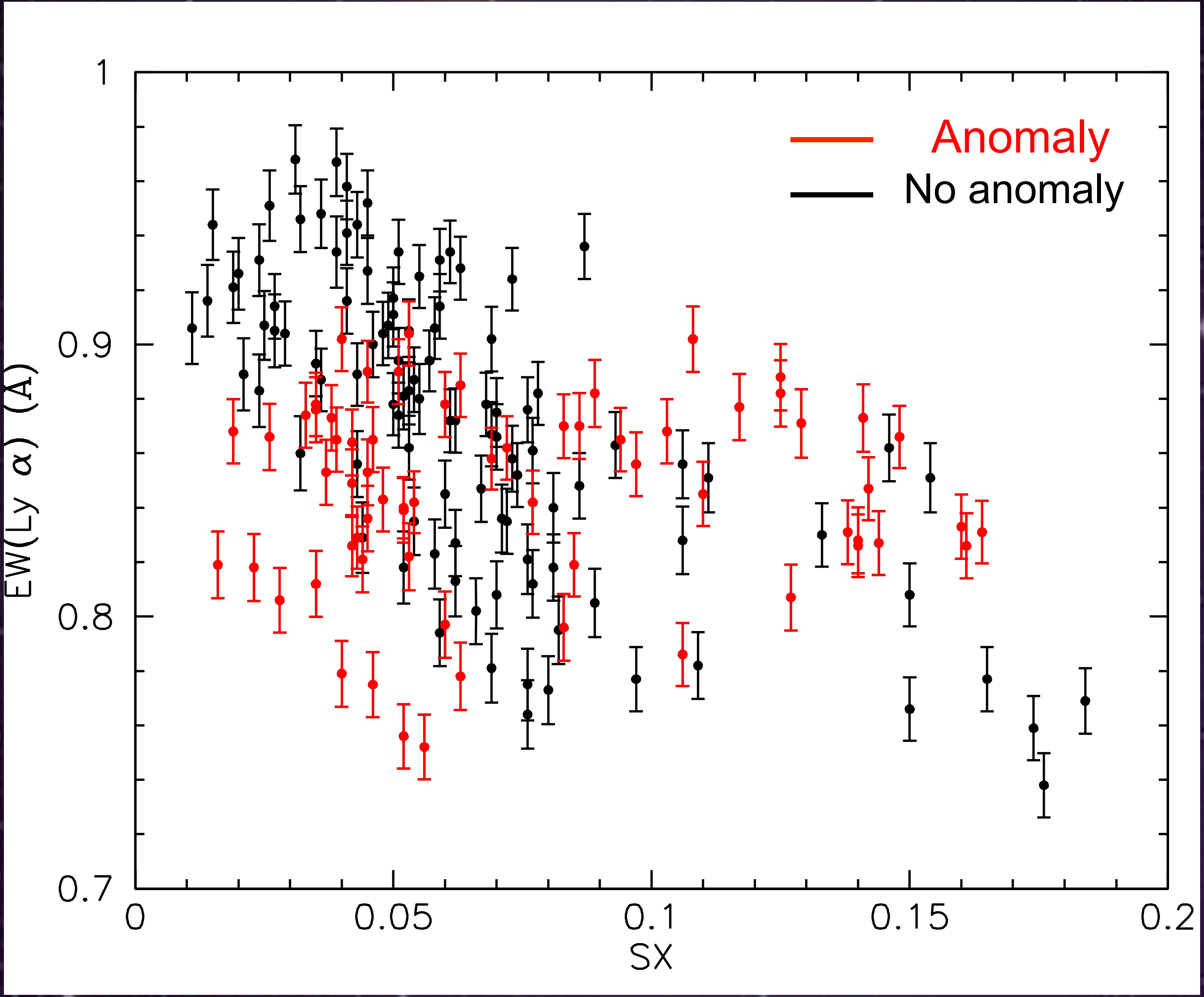
Poor Correlation for NV and F(1367)



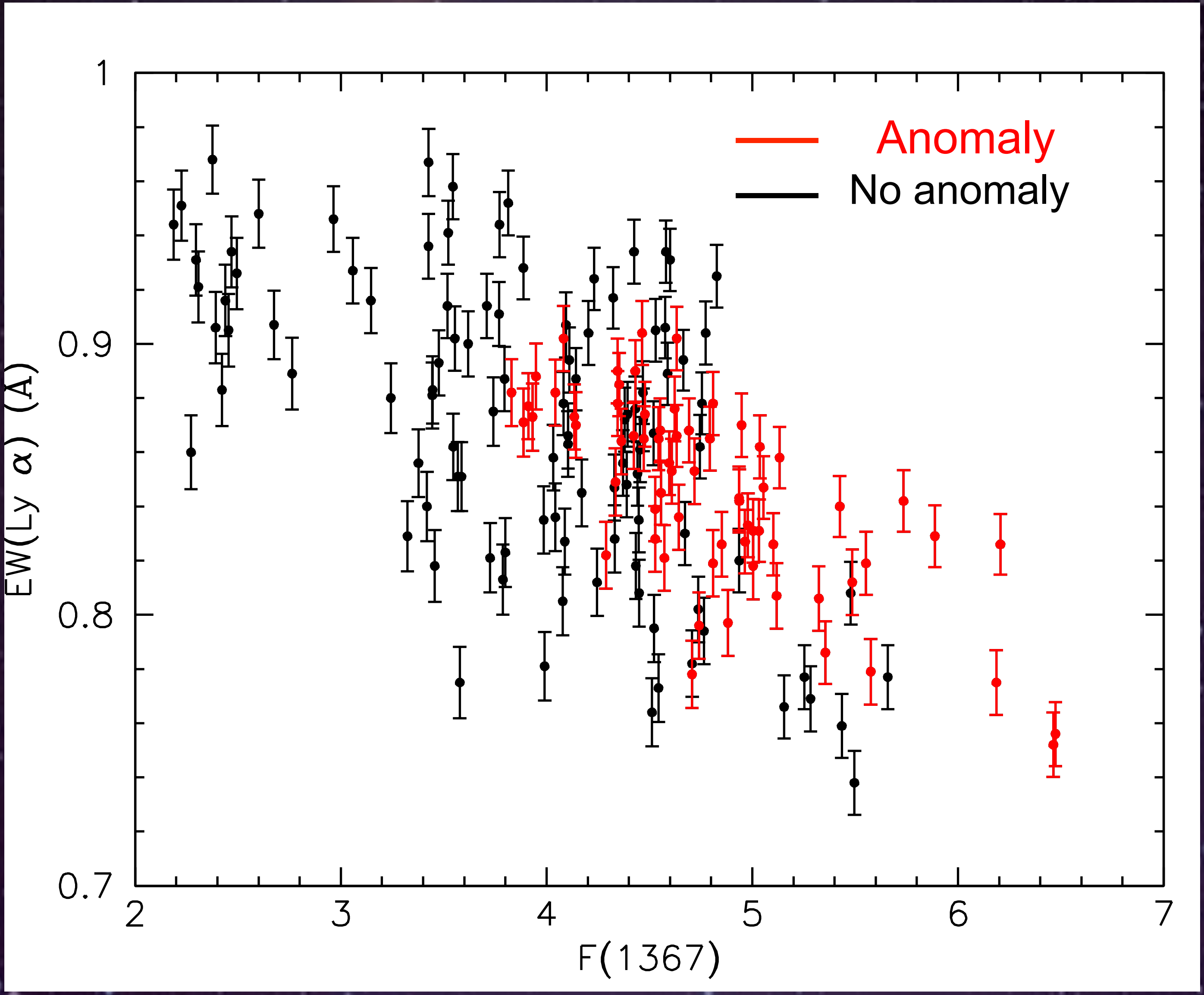
Better Correlation for NV and SX



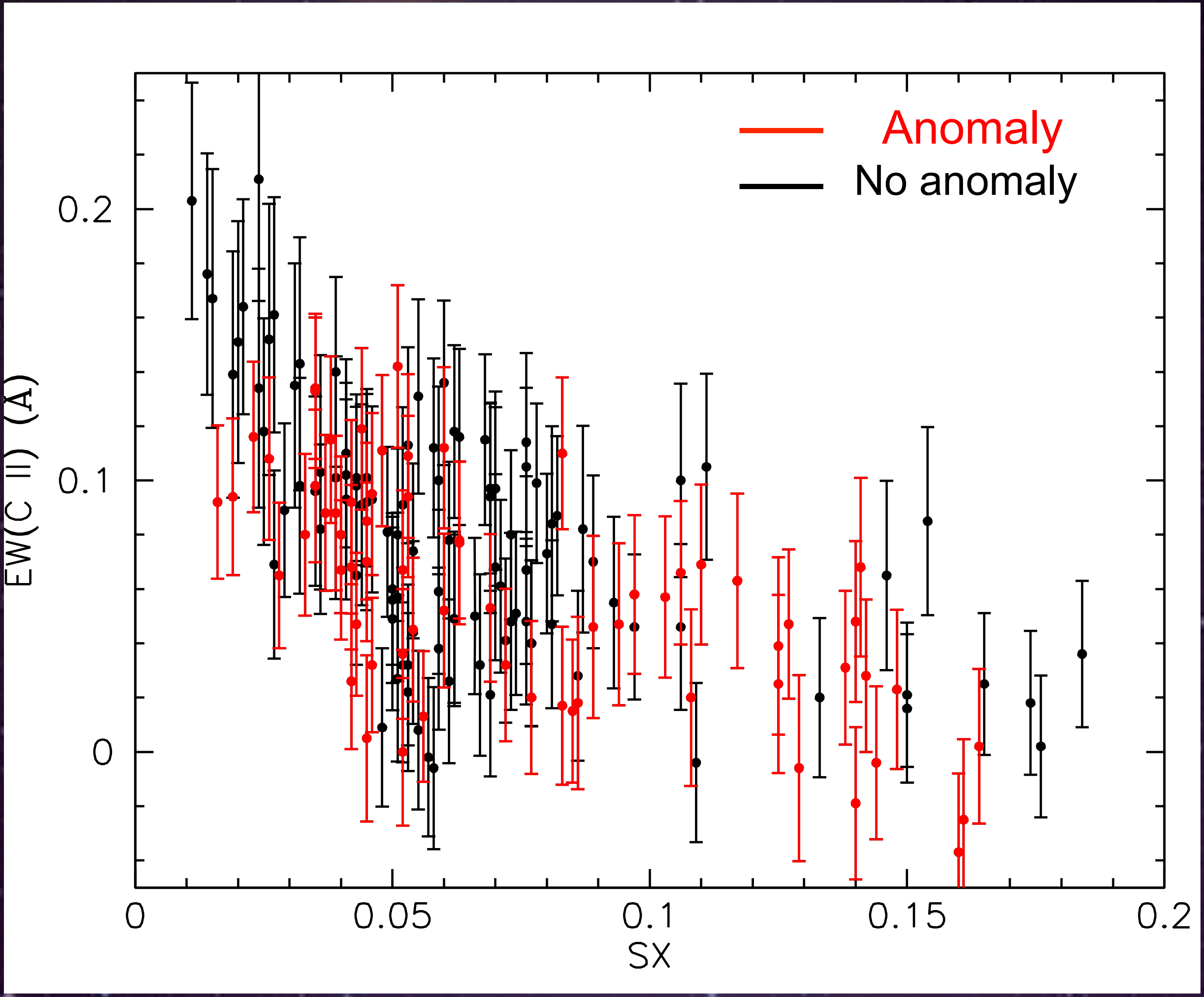
Poor Correlation between EW and SX in Lyα



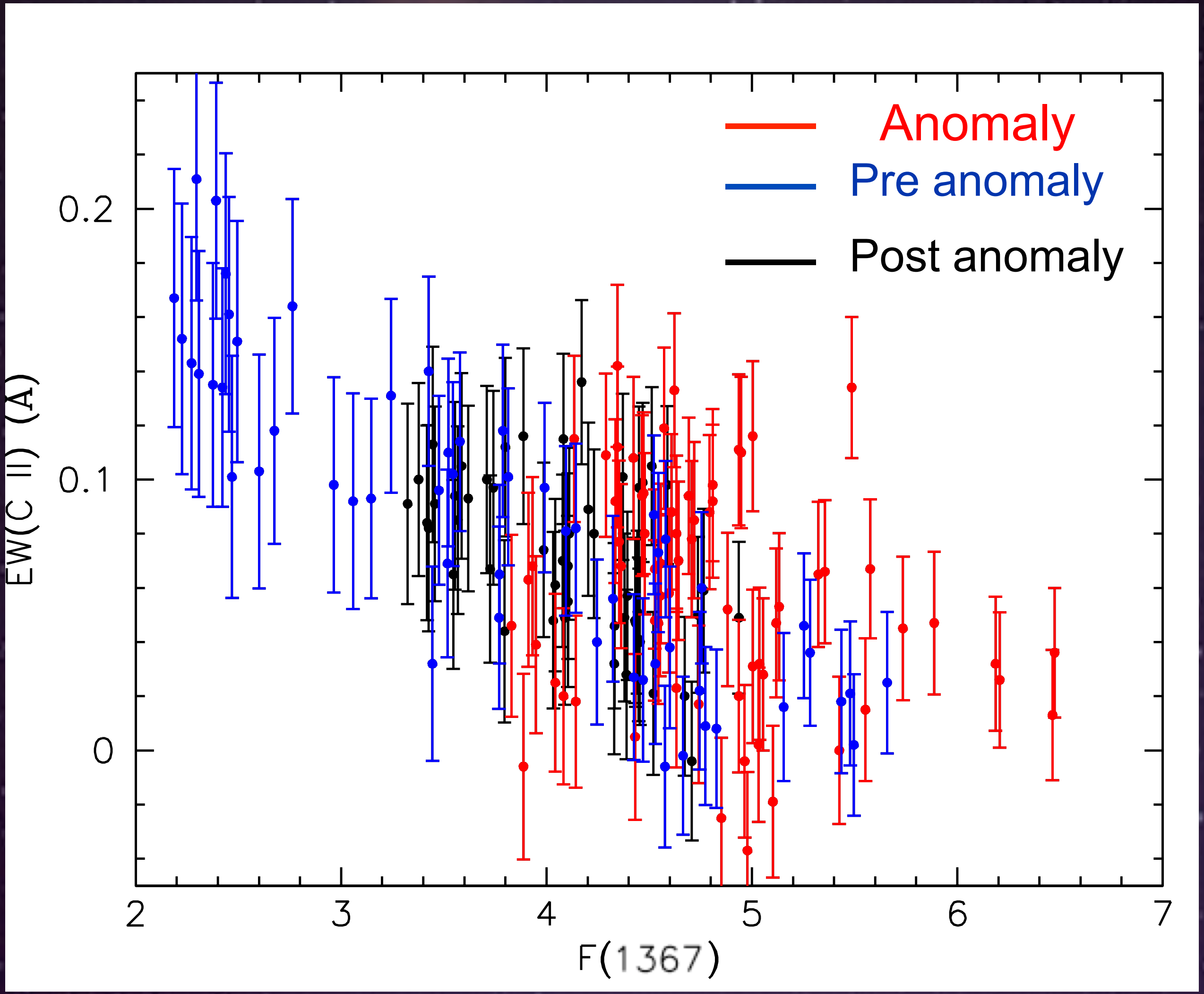
Better Correlation for Lyα and F(1367)



Poor Correlation for C II and SX



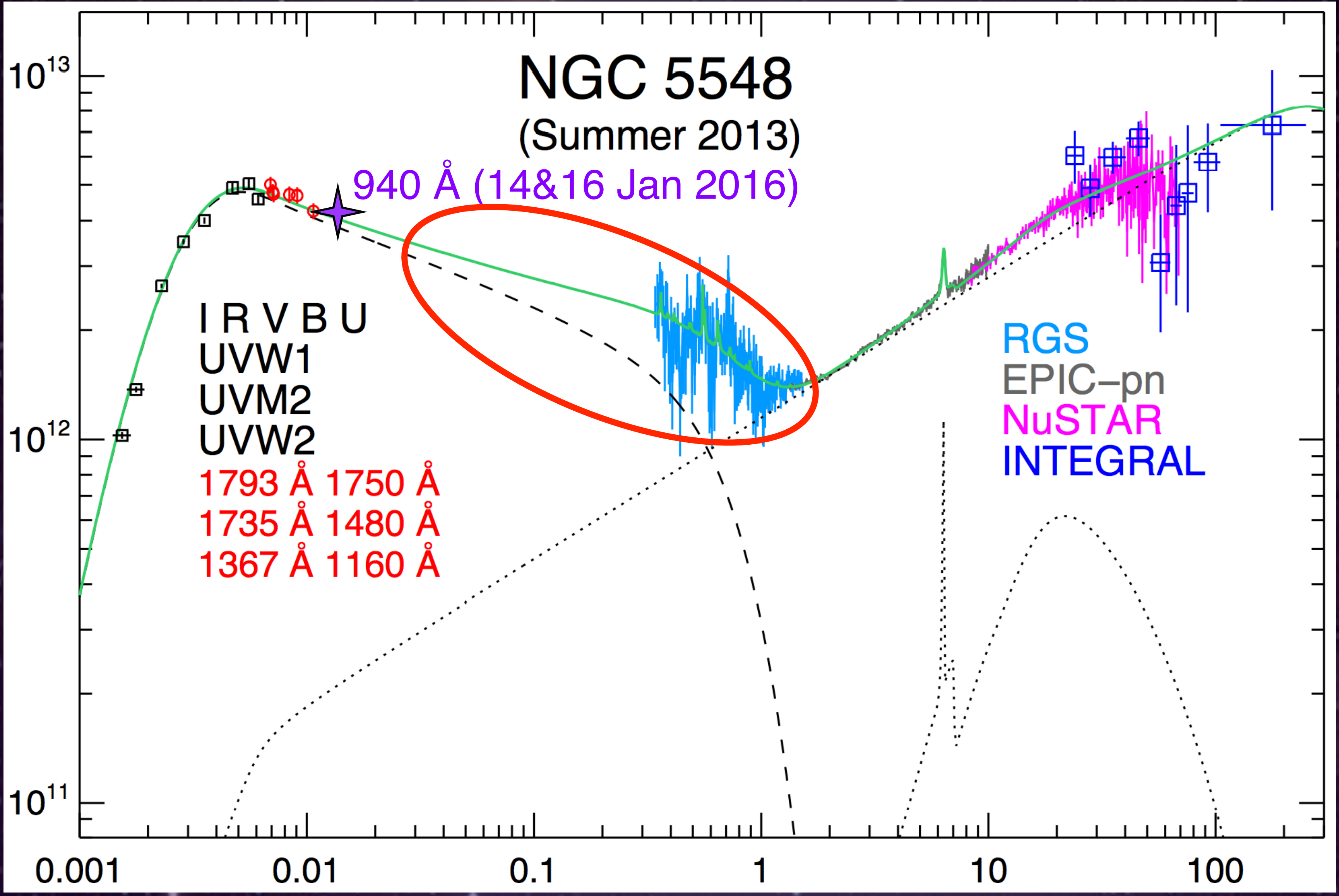
Better Correlation of CII with F(1367)



Inferring the SED in the Extreme Ultraviolet

- For the first 55 days, when everything correlates well, assume that the continuum shape is that shown in Figure 4 of Mehdipour et al. (2015). Call points on this curve “F0(1367)”, or “F0(IP)”.

NGC 5548 Spectral Energy Distribution



Inferring the SED in the Extreme Ultraviolet

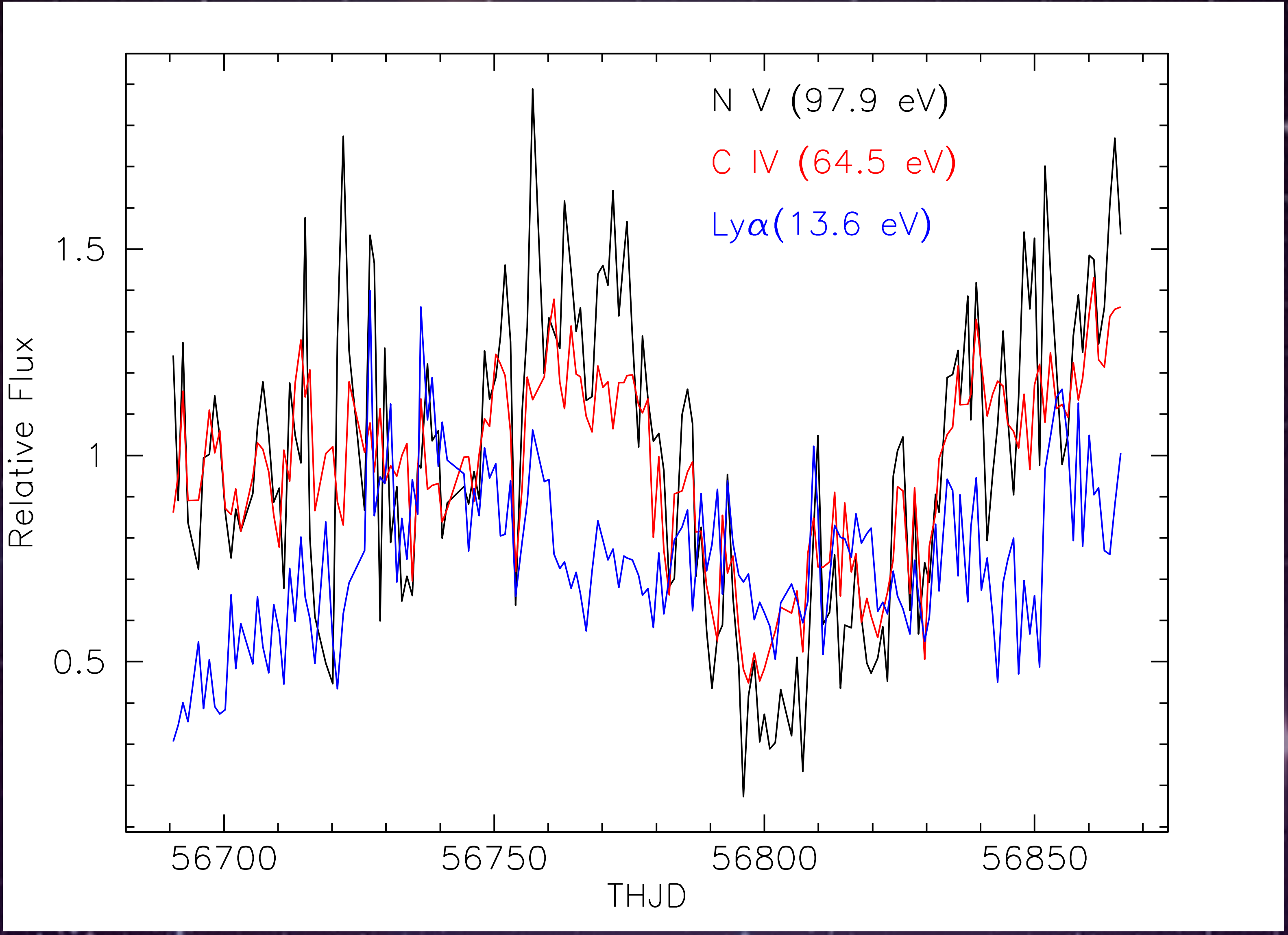
- For the first 55 days, when everything correlates well, assume that the continuum shape is that shown in Figure 4 of Mehdipour et al. (2015). Call points on this curve “F0(1367)”, or “F0(IP)”.

- Use the EW/F1367 correlation to then derive the proportionality between the line EW and the flux at its ionization potential:

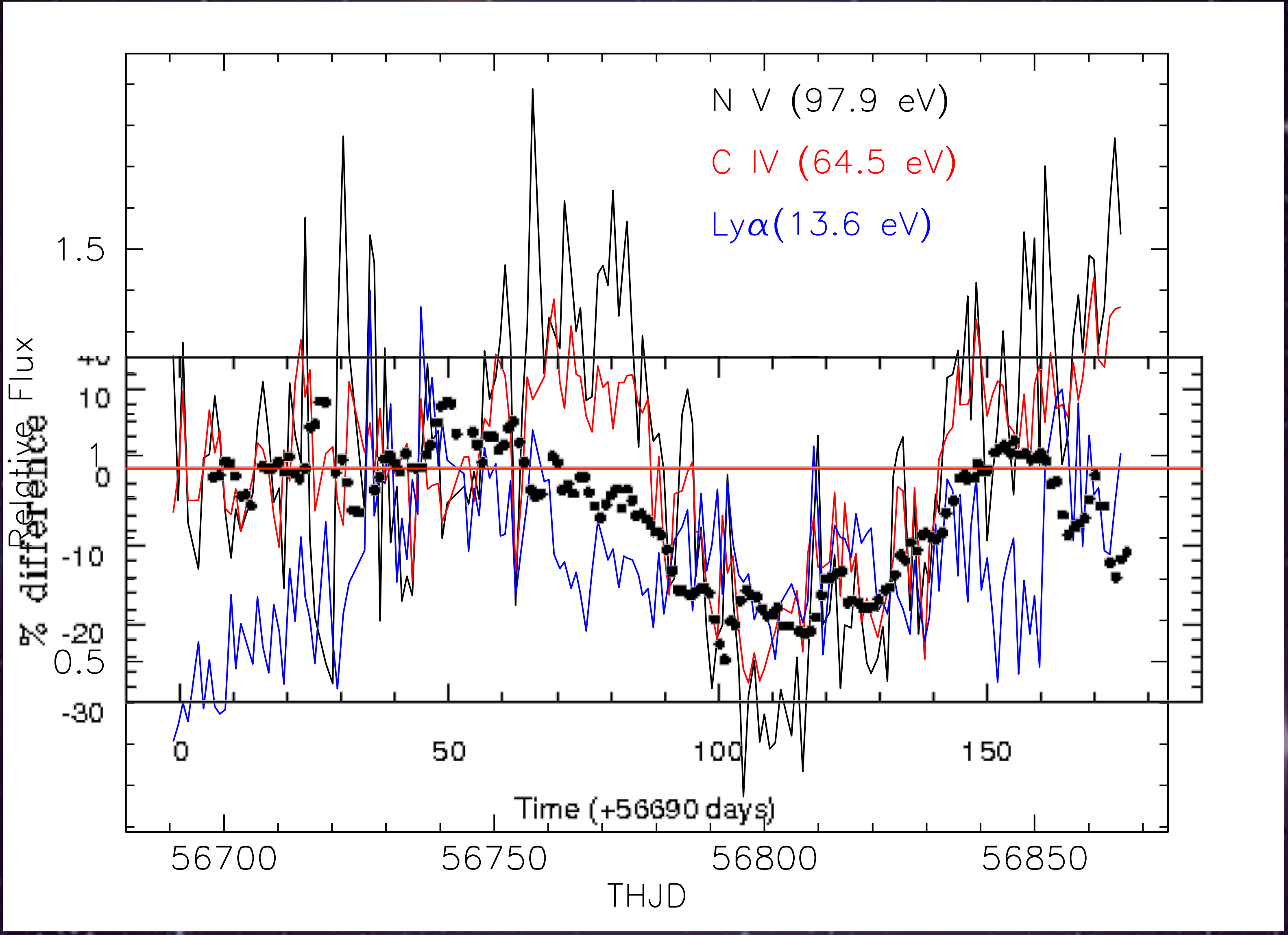
$$\mathrm{Flux(IP)} = \mathrm{F0(IP)/F0(1367)} * (\mathrm{EW} - \mathrm{a0})/\mathrm{a1}$$

- We can then derive an ionizing continuum light curve based on the EW light curve of each absorption line for their individual ionization potentials.

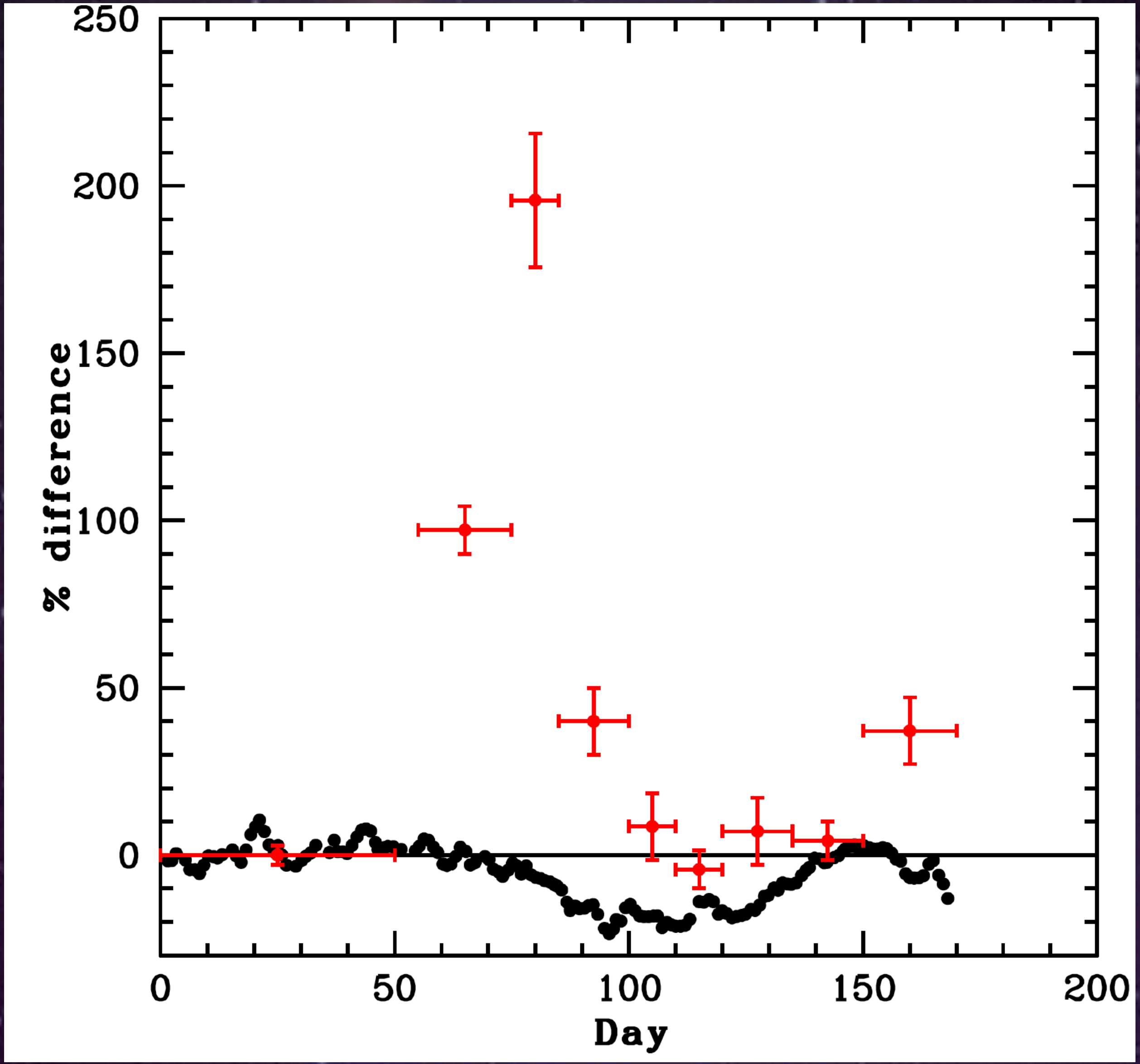
EUV Light Curves at the Ionization Potentials of NV, C IV, and Lyα



Comparison of Derived EUV Light Curves to the %difference for C IV (Fig. 1 of Goad et al. 2016)



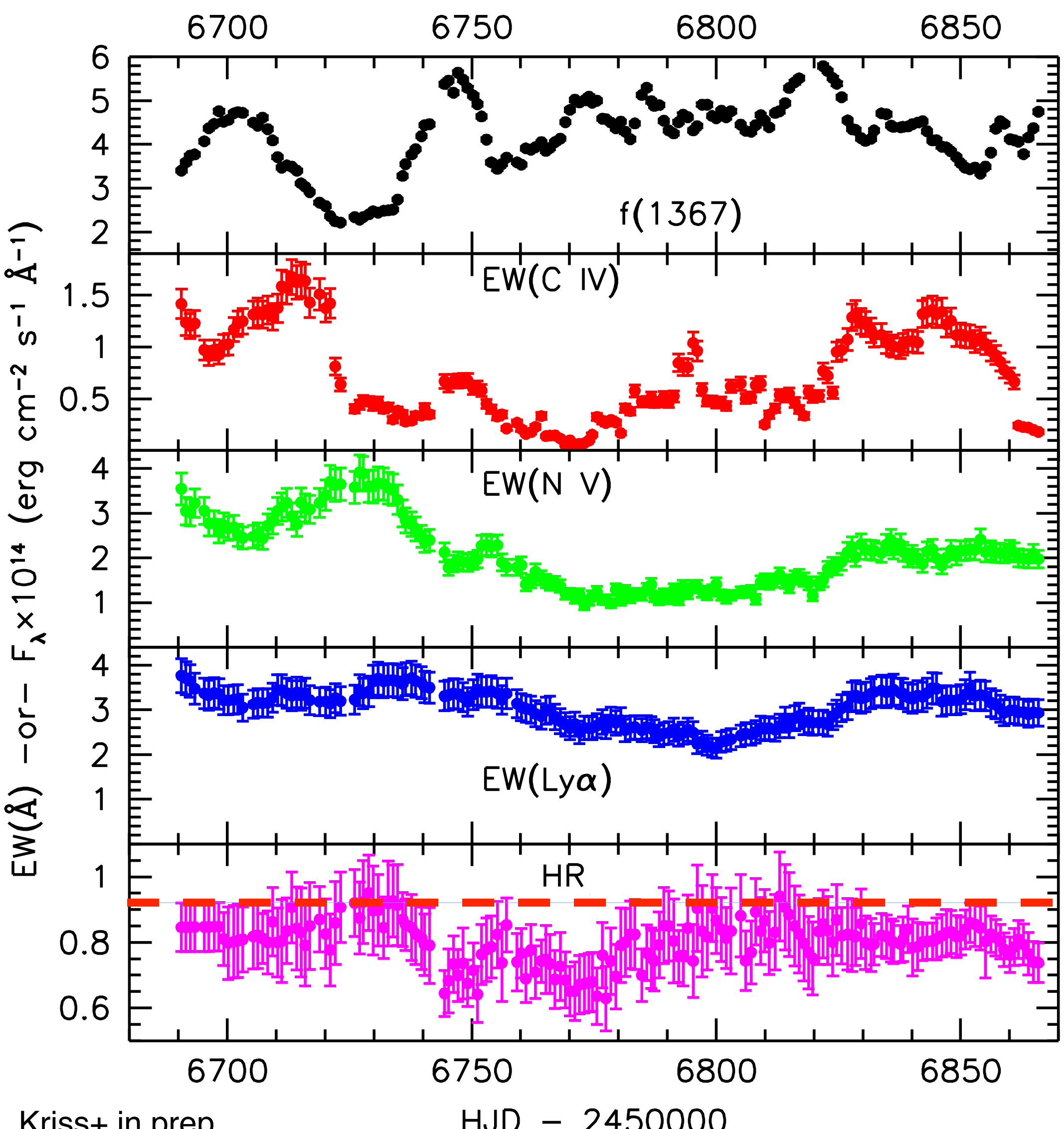
Soft X-ray Light Curve and the Anomaly (Mathur et al. 2017)



Implications for the BLR Holiday

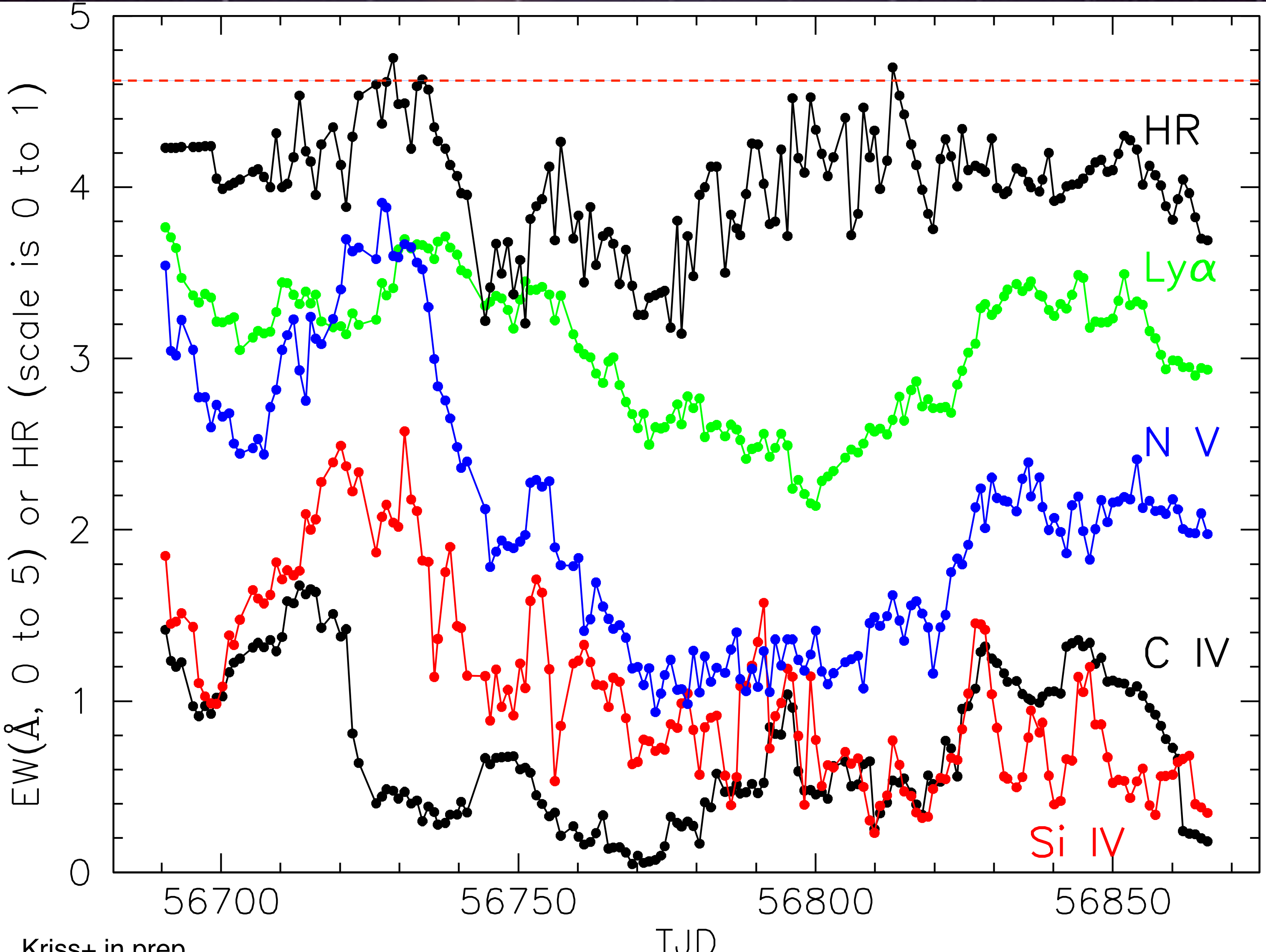
- Changing the ionizing SED is a desirable solution since it can explain at least two phenomena with one effect that does not require a special geometrical arrangement.
- Does suppressing the ionizing continuum above 30 eV have the desired effect on the relative response of the broad lines? For example, Paper IV says Lyα is suppressed by 9%, Hβ by ~30%, and C IV, He II and Si IV by 18-23%. Is this consistent with such a change in shape of the SED?
- Still to evaluate: Can simply changing the SED give the observed velocity dependence of the holiday onset and impact? (Need to evaluate this in the context of the gas distribution inferred from Anna and Keith's models of the BLR.)

The Broad UV Absorption Lines Also Vary with Time



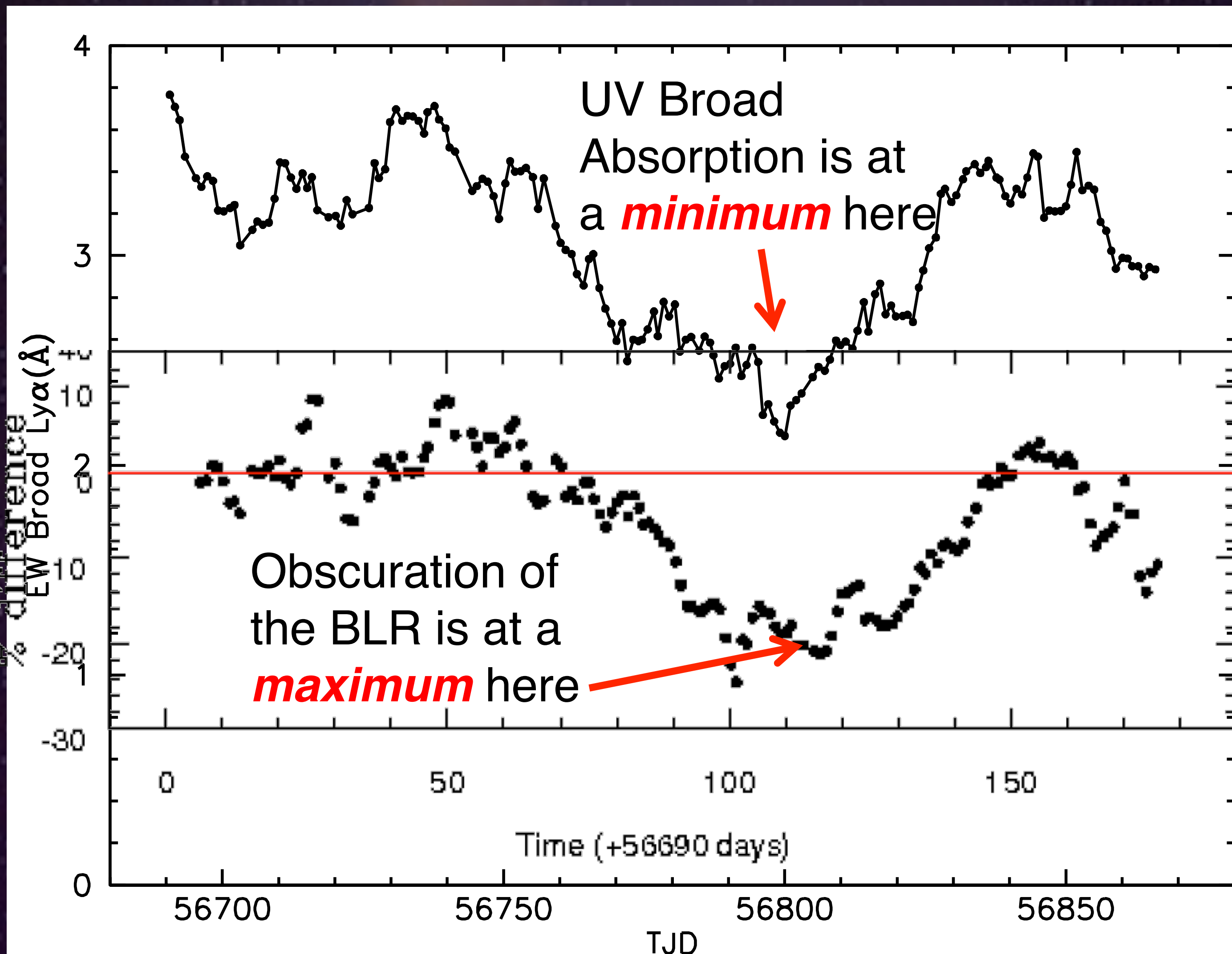
Kriss+ in prep

Light Curves for the Broad Absorption Features



Kriss+ in prep

Broad Absorption Compared to BLR "Obscuration" (BLR "Holiday", Paper IV)



Conclusions

- ★ Decorrelations in the equivalent widths of the narrow absorption lines of NGC 5548 are associated with the ionization potentials of the absorbing ions.
- ★ Lines with higher ionization potentials decorrelate more at times associated with the BLR holiday.
- ★ Using the absorption line strengths, we can infer the continuum flux at the line's ionization potential as a function of time.
- ★ Light curves for the inferred extreme ultraviolet continuum flux in the 13.6—97.9 eV range show high-energy diminutions strikingly similar to the flux deficits observed in the broad emission lines during the "BLR Holiday".
- ★ The cause of the BLR Holiday is not obscuration of the continuum source, but a change in the SED (at energies not visible to us).