NGC5548 De-explained

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Status Quo

- Two obvious explanations for the anomaly

  (1) “obscuration”

  - We don’t see the same SED that the BLR sees, i.e. the continuum continues to reach **us** during the anomaly, but it is not reaching the BLR (in the normal way)

  (2) SED change

  - The shape of the continuum itself has changed, i.e. we do see the same continuum as the BLR, but the relationship between the UV/optical data we observe and the driving (ionizing) continuum is different during the anomaly than at other times.

- Jerry found that the narrow absorption lines decorrelate with the continuum flux more or more strongly as we go up in ionization potential and that ionizing continuum light curves reconstructed from the NALs also show the anomaly.

- This favours SED change, rather than obscuration – i.e. it suggests that the ionizing continuum **even along our line of sight** is different (suppressed) during the anomaly.

Aside 1: I don’t really like the term “obscuration” for scenario 1 – it’s still perfectly ossible that absorption/obscuration is responsible for the SED change. The key point in that scenario is that we see something **different** than the BLR

Aside 2: There is nothing **that** unusual about the light curve / spectra we observe during the anomaly. In scenario 1, that would suggest that the obscuring structure is affecting the BLRs view of the continuum, but not ours. This, in turn, would seem to imply that our sight line is “special” – after all, the BLR is extended and presumably has many sightlines to the continuum. And at least a significant fraction of those would have to be affected. Yet ours isn’t. Not impossible, but unlucky?

Reconstructing the Ionizing Continuum Light Curves from the Broad Emission Lines

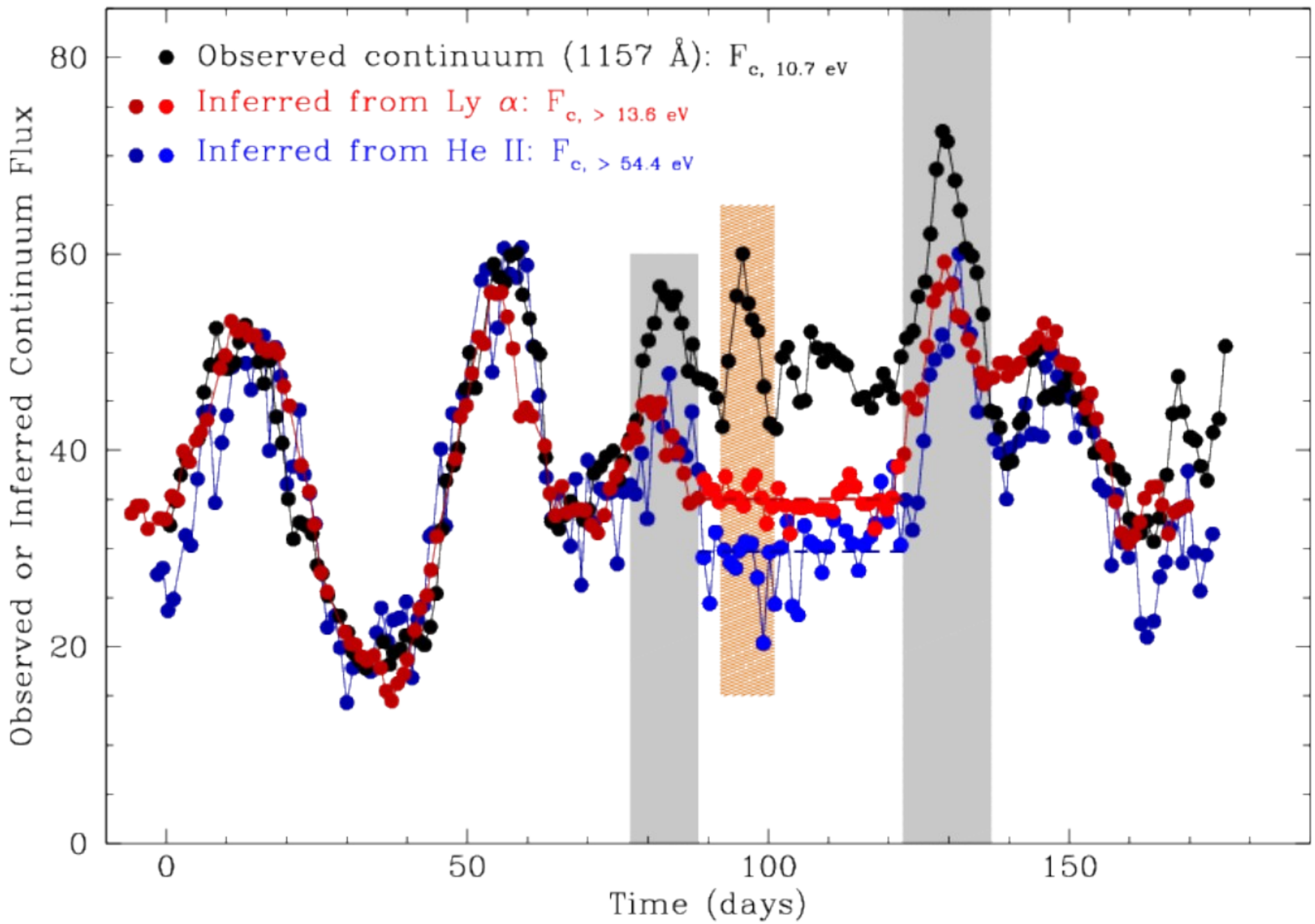
- Two of the prominent BELs in NGC5548 are Ly α and He II 1640 A.

- These are **recombination** lines, and the BLR is photo-ionized, so we might expect them to track the flux in the relevant ionizing continua pretty faithfully (at least over a moderate range in ionizing fluxes)

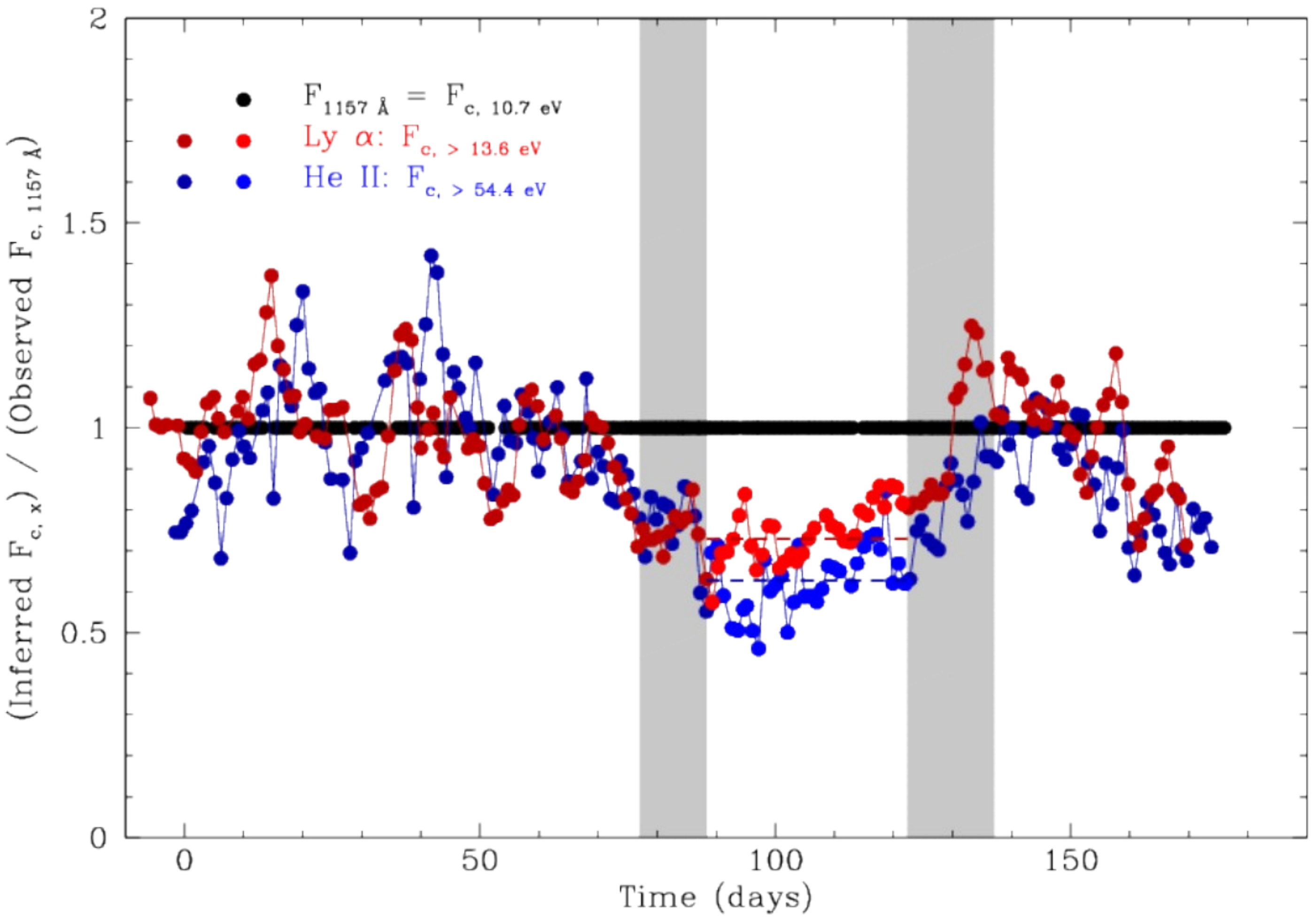
- If so, we can reconstruct the Lyman (13.6+ eV) and He II (54+eV) continuum light curves during the anomaly from the behaviour of the line fluxes.

- We'll assume that **before** the anomaly, the 1158 A continuum flux tracked the ionizing flux in both continua faithfully. We can then infer the ionizing flux **during** the anomaly by shifting and scaling the line flux light curves to match the 1158 A continuum **before** the anomaly. We then retain the same shift and scale factor for the whole light curve.

Reconstructed Ionizing Continuum Light Curves (matched to 1158 A)

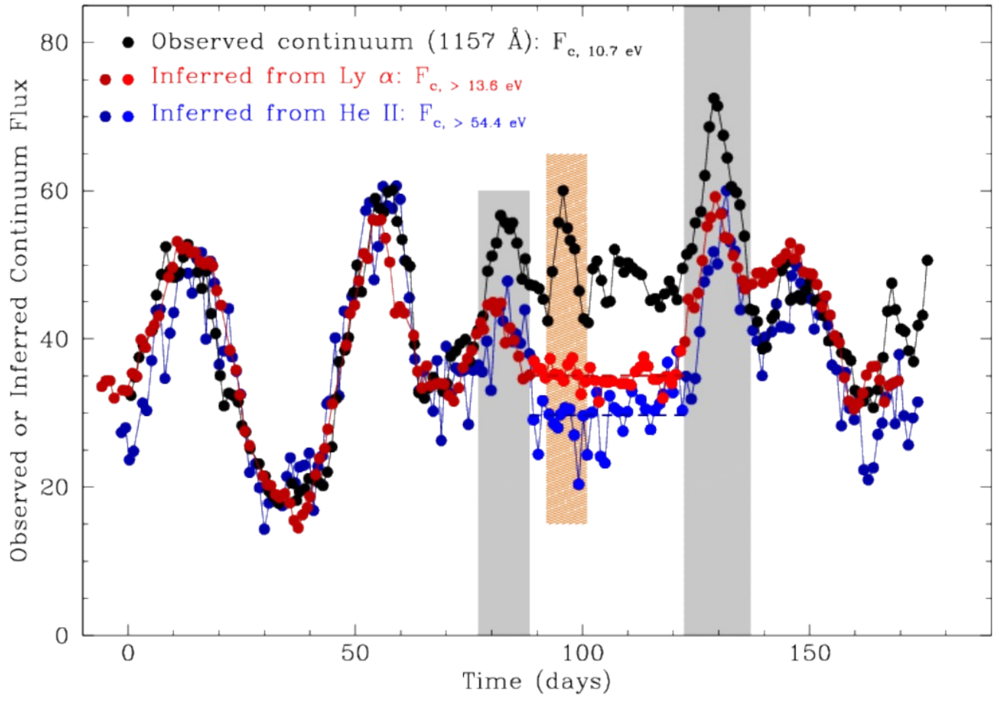


Reconstructed Ionizing Continuum Light Curves)
(divided by 1158 A)



- So far, this is nothing really new
  - It's really just a different way of visualizing and interpreting the line fluxes during the anomaly
  - As such, it can't really disagree with any of Mike and Kirk's conclusions (and it doesn't)
  - The "new" interpretation also seems to be broadly consistent with Jerry's conclusion that the ionizing continua **do** change during the anomaly

- Here is where it gets more interesting – consider again the reconstructed continuum light curves, but let's pay particular attention to the shaded regions this time
  - The **grey** shaded regions mark "local peaks" in the 1158 A continuum light curve **right at the beginning and right at the end of the anomaly**
  - The **red** shaded region marks a "local peak" in the 1158 A continuum light curve **right in the middle of the anomaly**

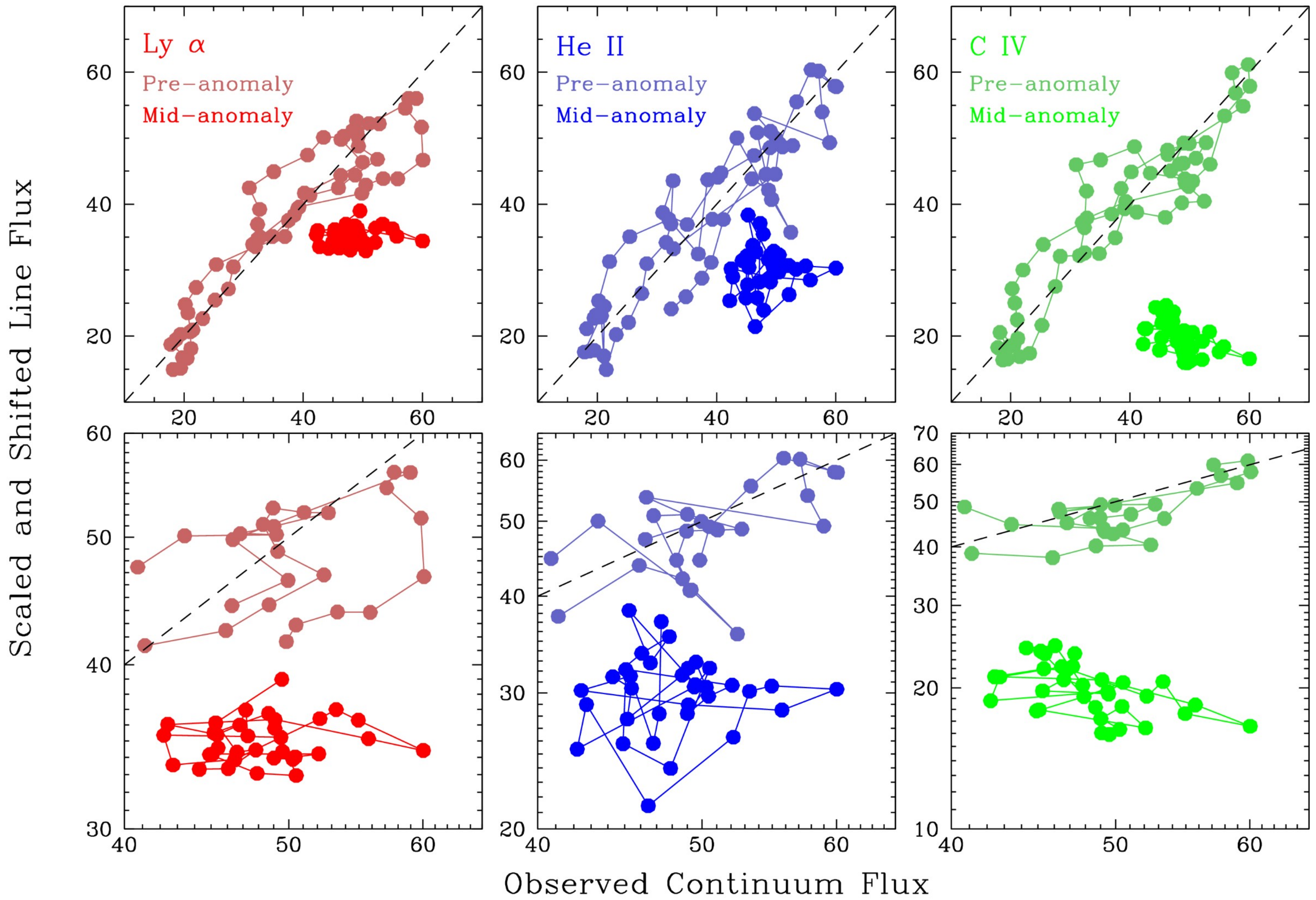


- The striking thing here is that the peaks in the grey-shaded regions **<u>are</u>** reflected in the emission line light curves, but the peak in the red-shaded region **<u>is not</u>.**

Two effects, not one

- If the anomaly simply consisted of an abrupt change in the SED, we'd expect a change in the **strength** in the line response (i.e. in the strength of the lines)...
- ...but we would **not** expect that the lines would stop responding to the observed continuum
- I think this means that there are two distinct things going on during the anomaly:
  - The anomaly starts and ends with **a simple reduction in line flux (i.e. a weaking of the response)** relative to what we'd expect based on the 1158 A flux at other times
    - This is what's happening in the grey-shaded regions
  - Near the middle of the anomaly, there must (also) be **a decoupling of the 1158 A continuum from the ionizing continuum**
    - This is why there is no line response to the 1158 A variability in the red-shaded region
- It's perhaps not unreasonable that the 1158 A and the ionizing continua could arise from distinct sources, which would allow them not to trace each other (e.g. as in Emma and Chris' picture)
- However, this still begs the question why the two **do** track each other normally – just not during the anomaly
- I should add that Mike and Kirk do touch on these issues in their paper, but I for one hadn't really digested this

Visualizing the decoupling during the anomaly



What about the continuum?

- So far, we've been thinking mainly in terms of the unobserved ionizing continuum doing something unusual during the anomaly

- But what if it's the UV continuum that's messing us around?

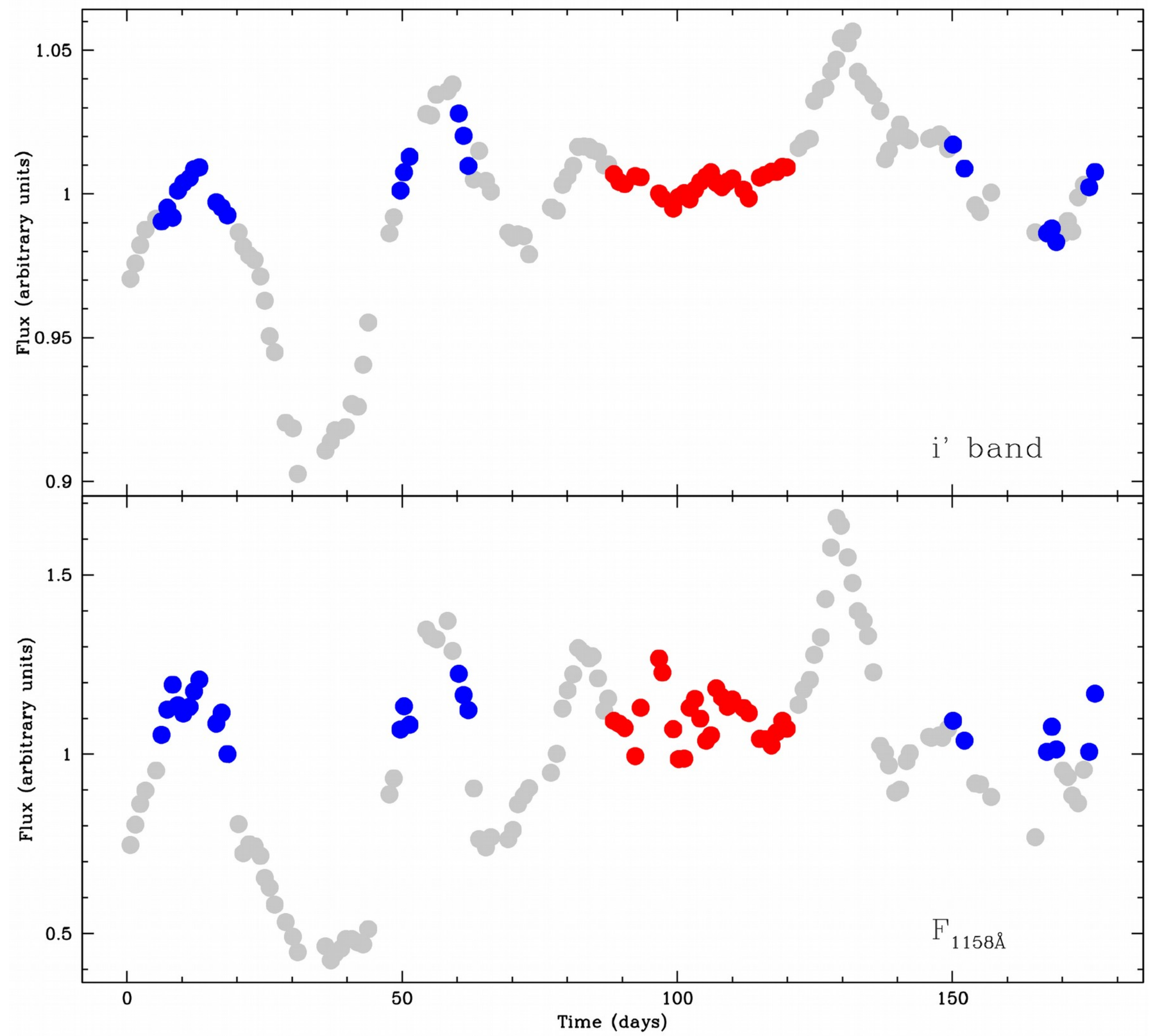
- For example, could it be that, during the anomaly, there is simply a new, variable UV SED continuum component and that **that** is why the lines no longer track the UV continuum?

- Even more generally, **does the anomaly only affect the lines/ionizing continua or is there also an effect on the correlation between different observed continuum bands?**

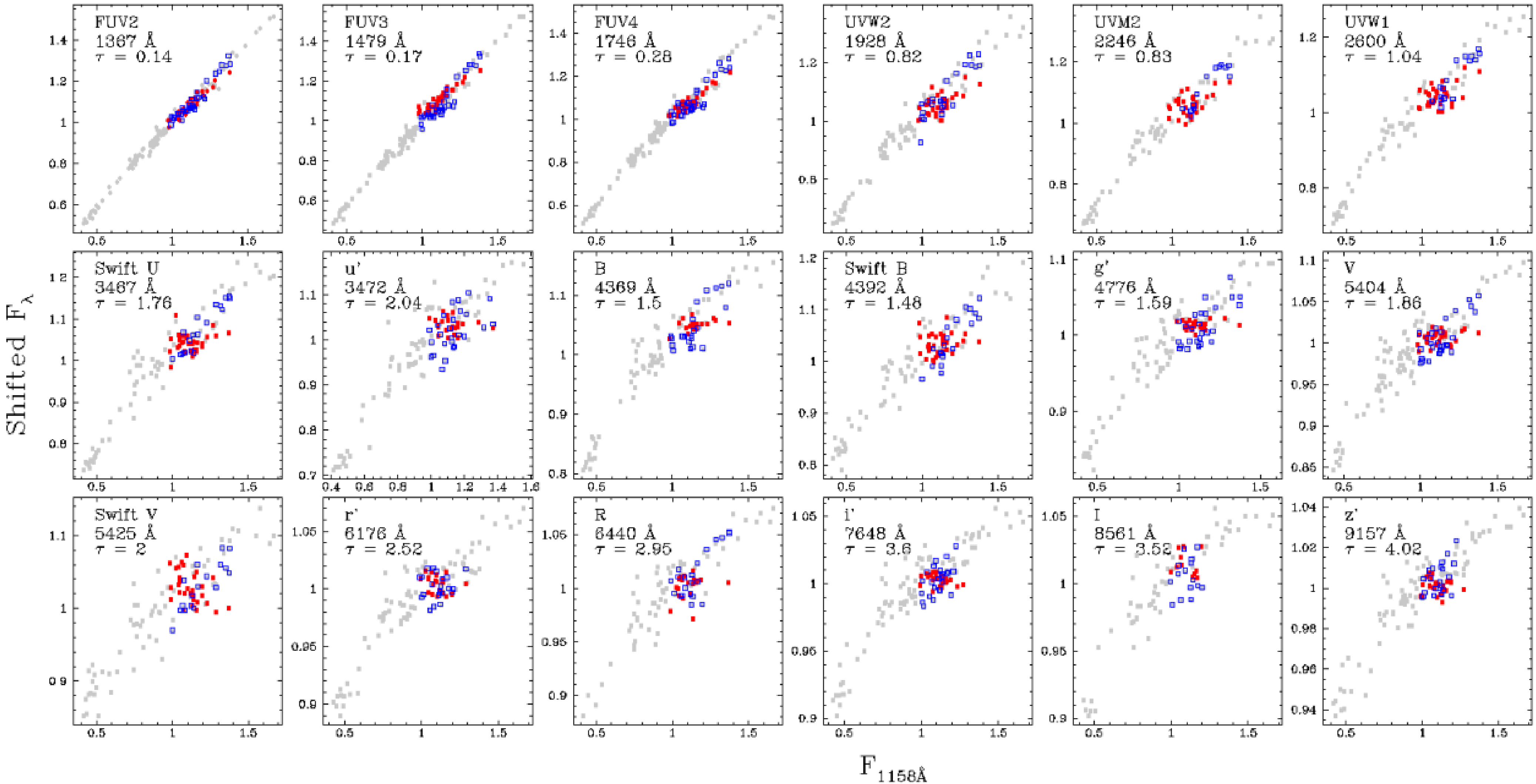
Continuum-continuum correlations

- In the following pages I'll explore the flux-flux correlations between the 1158 band and each of the other continuum bands
- For each pair of bands, I'll remove the relative lag between the bands
- I'll highlight in red points that come from the middle of the anomaly
- I'll also highlight in blue points that come from the same flux range (in the 1158 A band) as the red points, but that come from well before or after the anomaly
  - So the blue points tell us what's "normal" behaviour in the 1158 A flux range during which we see the anomaly

Color-coding example for 1158 band vs i' band



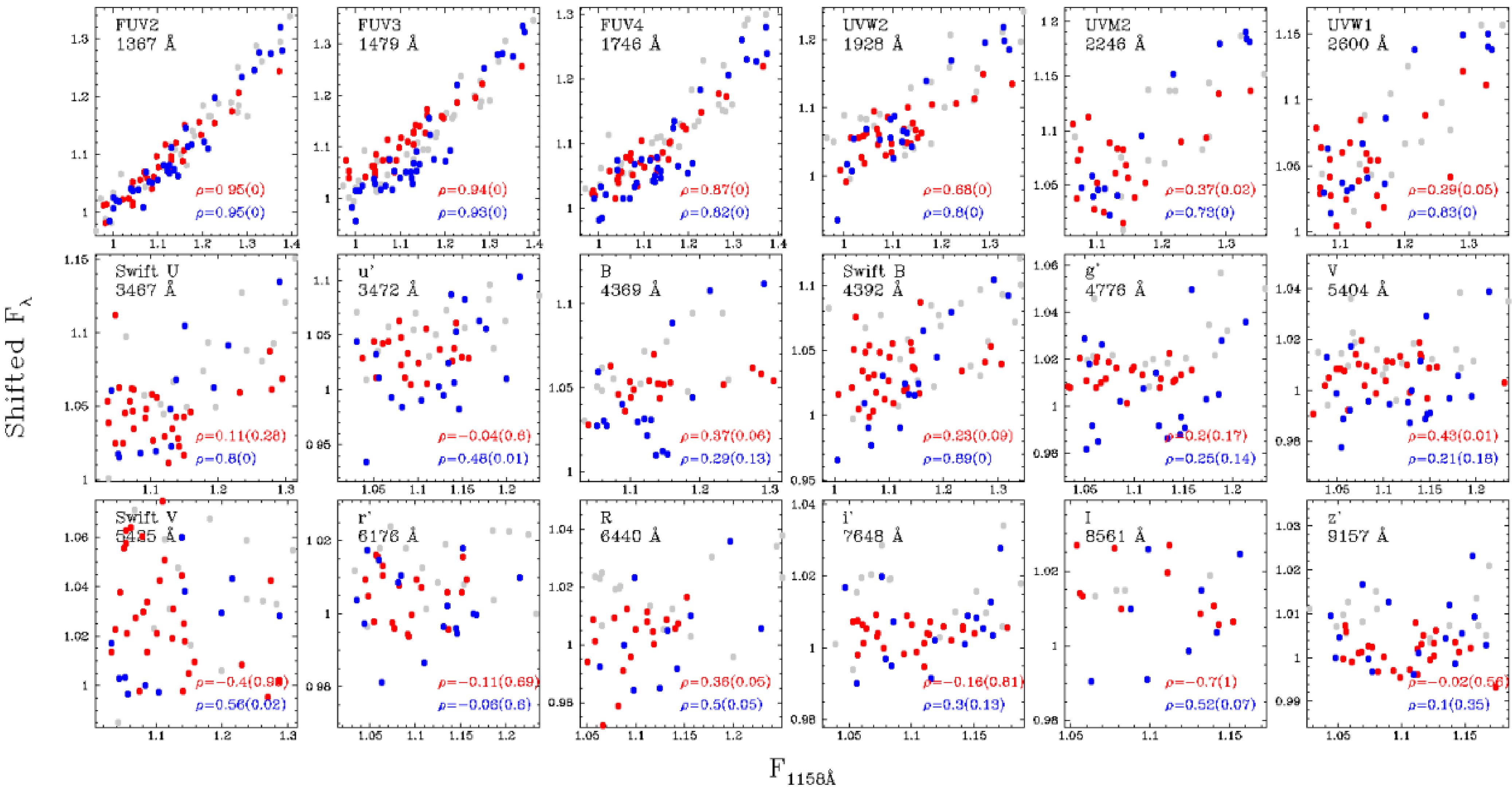
Continuum-continuum correlations
(full flux range)



Continuum-continuum correlations

(zoom-in on anomaly flux range)

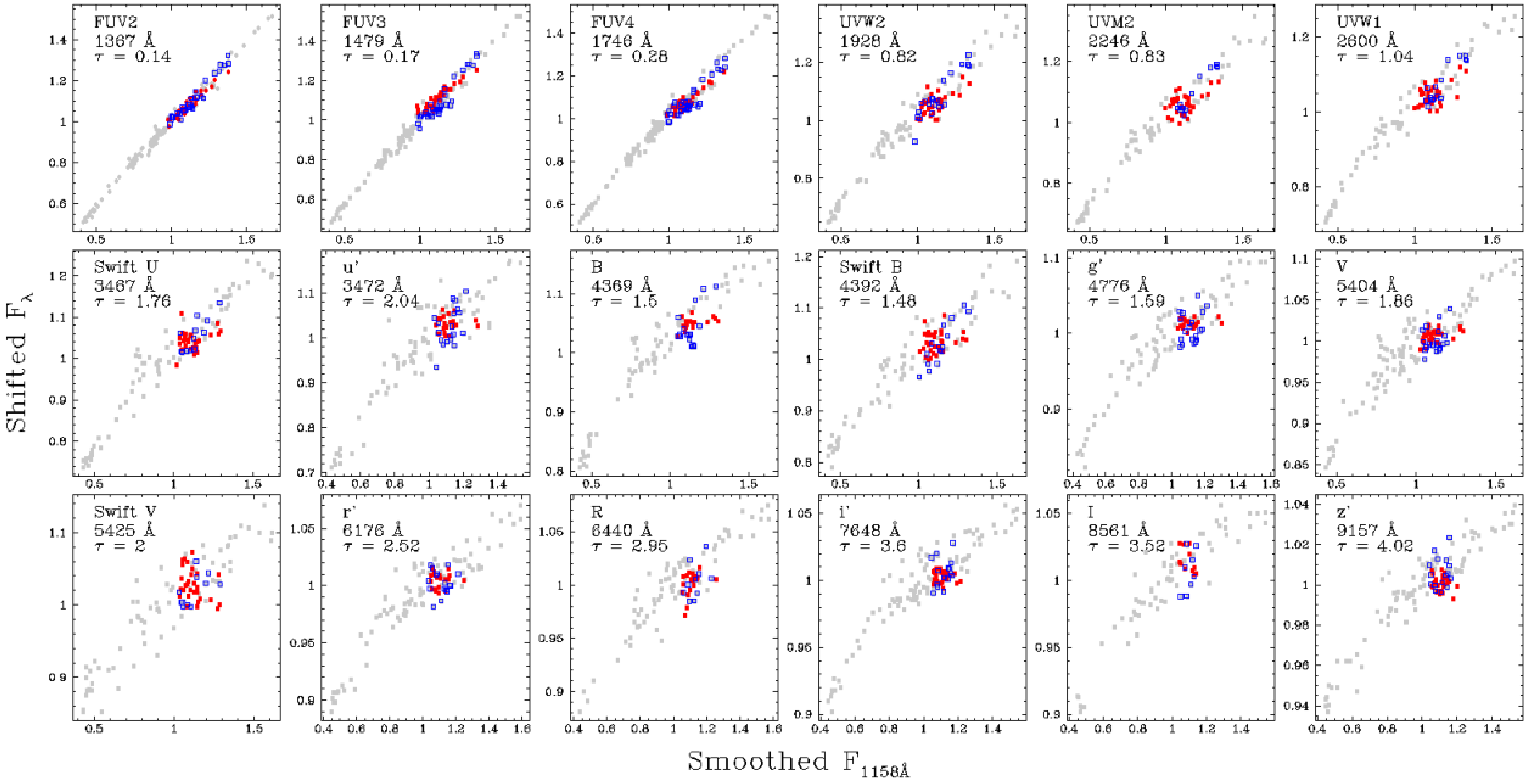
[ρ = x(y) denotes a correlation coefficient of x, which has a p-value of y]



Continuum-continuum correlations

- In general, we expect the **width** of the transfer function to be comparable to the mean **lag**
- This is true, for example, for reprocessing in a disk annulus
- We therefore have to keep in mind that there is a “natural” decorrelation between different bands, since reprocessing doesn’t just **shift** the light curves, but also **smoothes** them
- In order to test how important this is here, I have calculated the transfer functions for thin disk rings with radii corresponding to the relative lags between our bands
- Rather than correlating the actual 1158 A flux against, say, the z’-band fux, I then convolve the 1158 A light curve with this transfer function and correlate **that** against the z’-band flux
- So, effectively, I use the 1158 A light curve, the measured lags and the assumption of reprocessing in disk annuli to **predict** the light curves in all of our bands
- I can then check whether the quality of that prediction is different inside and outside the anomaly

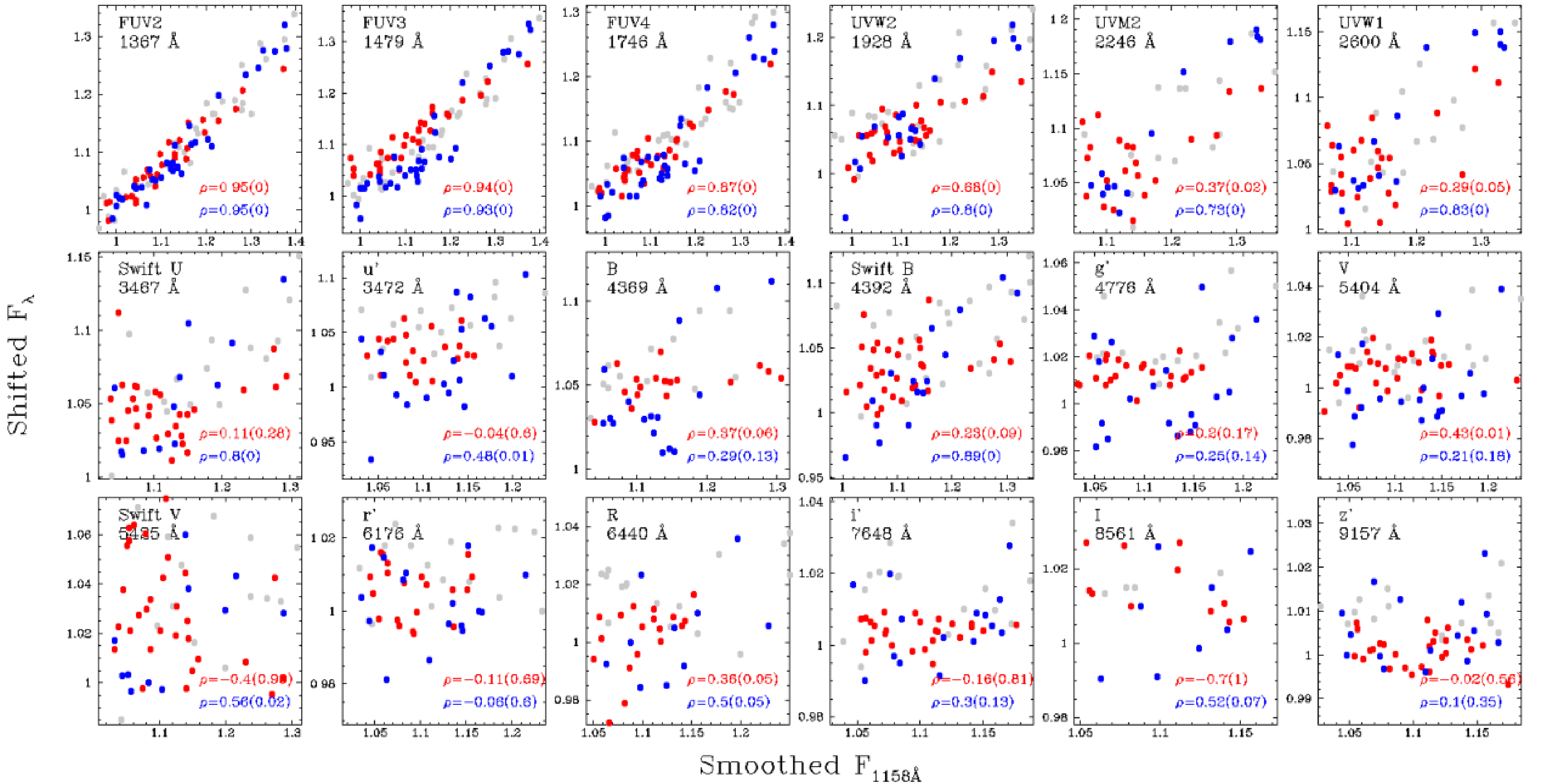
Continuum-continuum correlations
(full flux range; with transfer function)



Continuum-continuum correlations

(zoom-in on anomaly flux range; with transfer function)

[ρ = x(y) denotes a correlation coefficient of x, which has a p-value of y]



Continuum-continuum correlations: Conclusions

- Continuum bands definitely correlate less and less well as the wavelength separation between them increases
  - This is sort of expected (see earlier)
  - But the effect doesn't seem to go away even if we try to correct for it with a disk-ring-based transfer function

- During the anomaly, continuum bands do seem to correlate less well with each other than at other times, even if we consider only the limited flux range that corresponds to the anomaly
  - This suggests that the anomaly does not only affect the ionizing continuum
  - It may also have implications for attempts to infer transfer functions from the data (both for lines [Keith: MEMECHO] and continua [David: CREAM])