IACHEC XV : Bad Endorf : 25 Apr 2023

Problems of High-Resolution:
Background, atomic lines, statistics

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Briefly…

- High-resolution spectra come with unintuitive challenges: sparsity, detectability, and background
- Walk through of example analysis of HRC-S/LETG observation of RT Cru to set upper limits on line fluxes

  Zhang, Algeri, Kashyap, Karovska (2023 MNRAS 521, 969) https://arxiv.org/abs/2302.00718

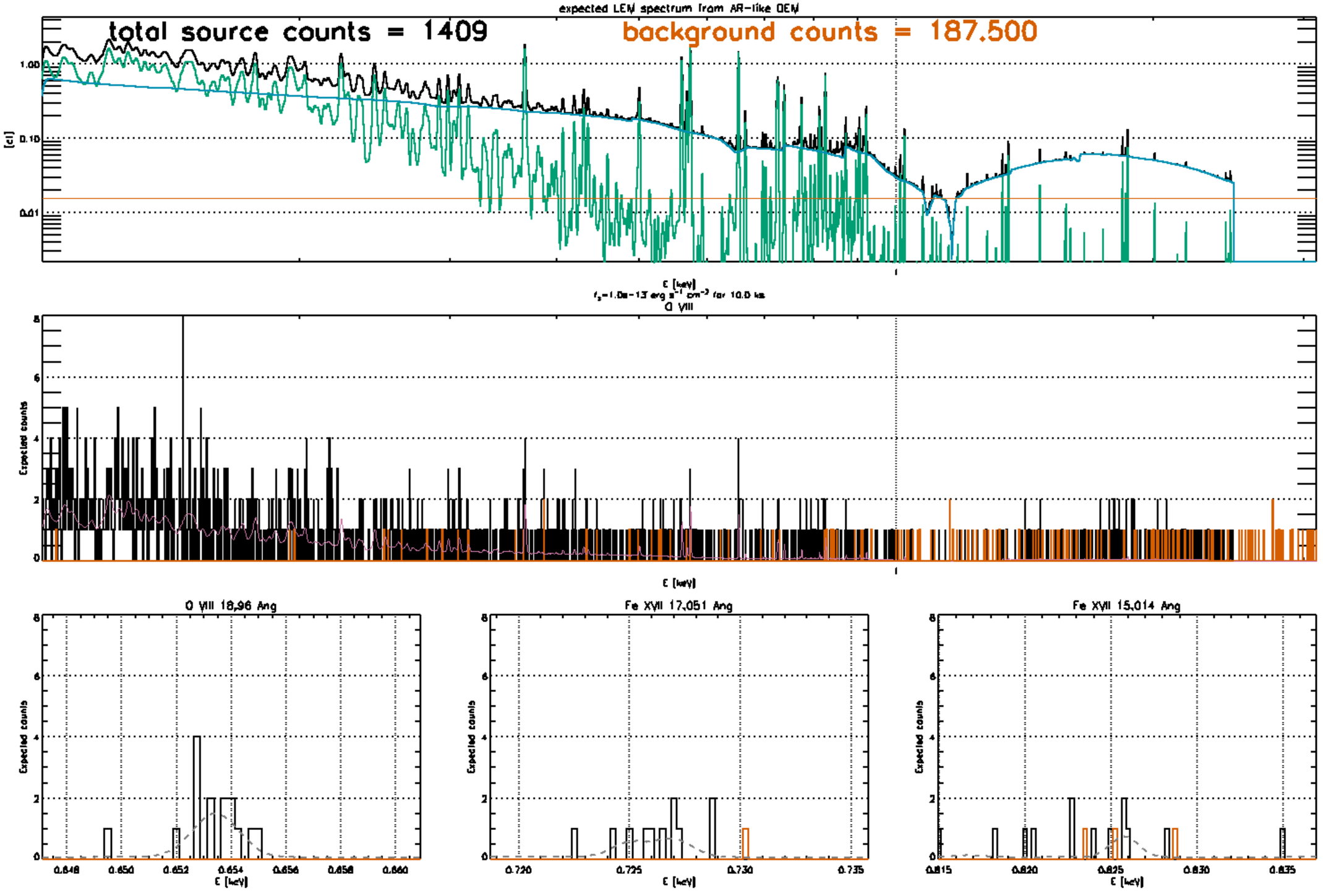
- Future application to calibration problems: HRC degap, evaluating background models

SPARSITY

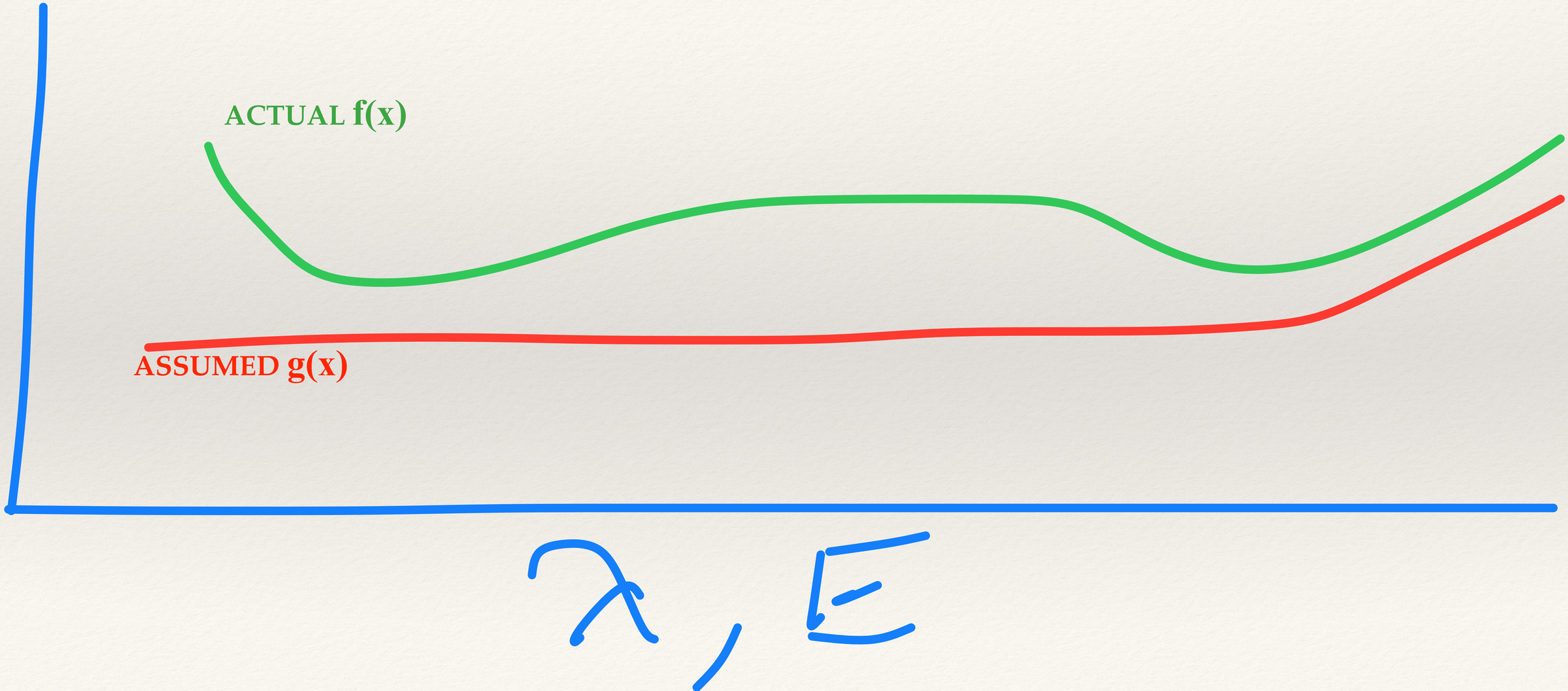
In the era of XRISM, ARCUS, LEM, etc., we will have more than enough weak sources observed at spectral resolutions currently limited to X-ray bright sources.

Top: LEM line spectrum of a star with $f_X=10^{-13}$ erg/s/cm^2 in 10 ks.

Middle/bottom: All that rich information will be completely missed, with even background confounding even the brighter lines.



how well do you know your background?

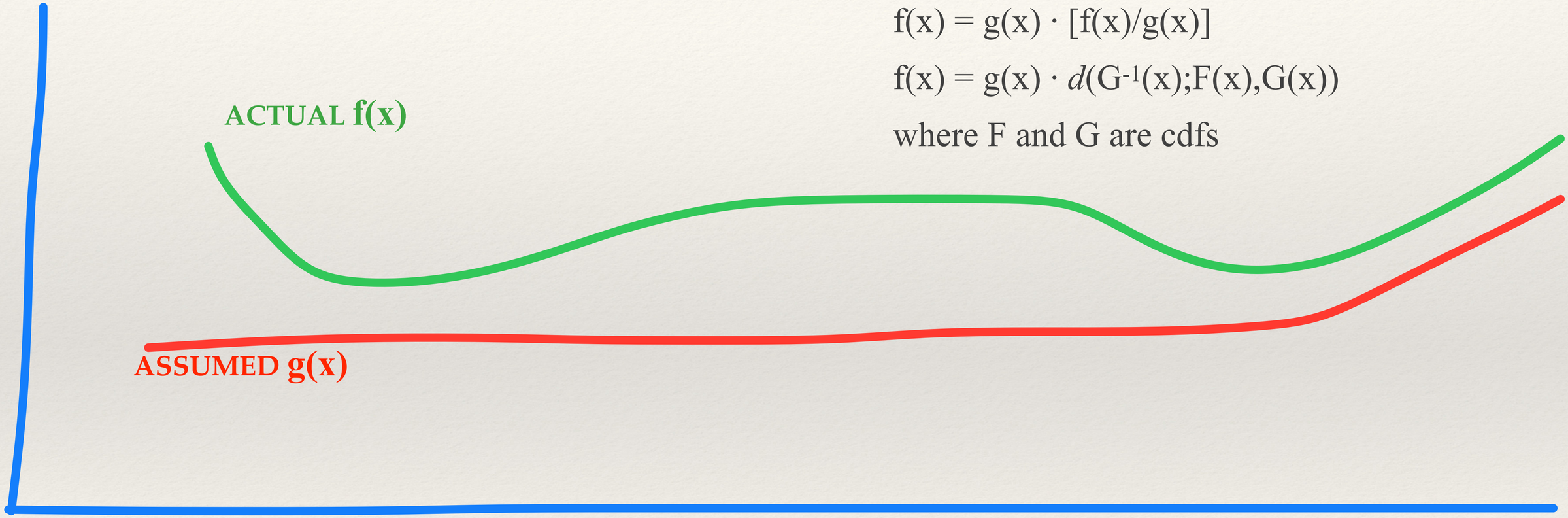


how well do you know your background?

$f(x) = g(x) \cdot [f(x)/g(x)]$

$f(x) = g(x) \cdot d(G^{-1}(x);F(x),G(x))$

where F and G are cdfs



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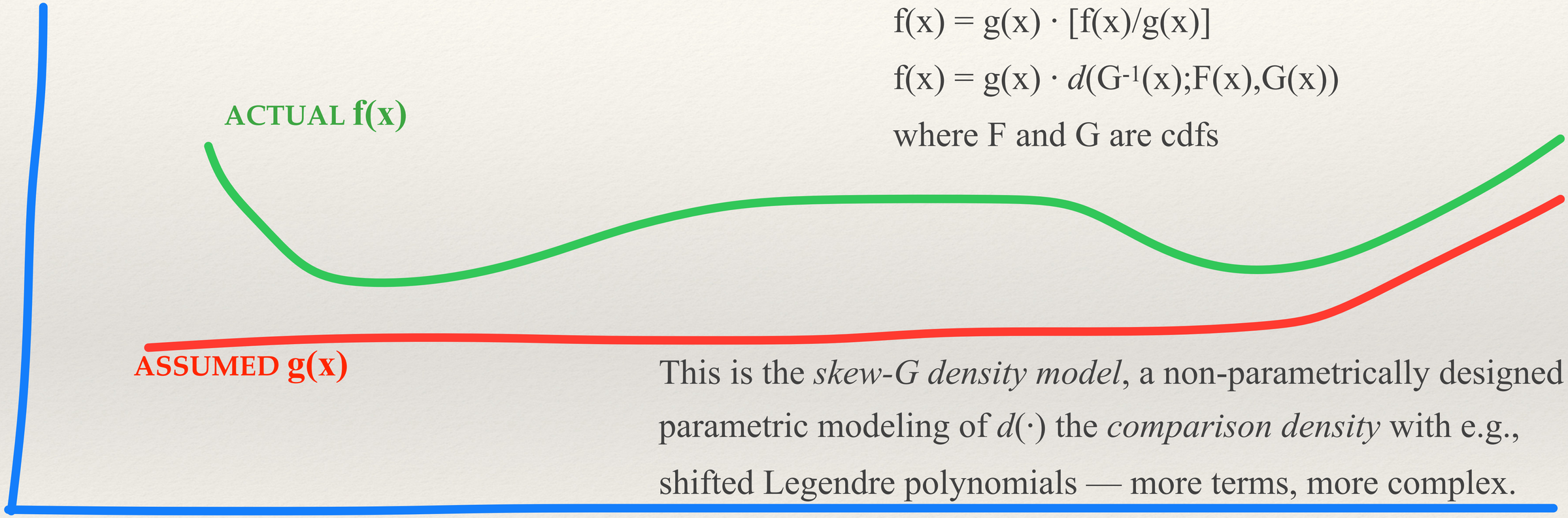


This is the *skew-G density model*, a non-parametrically designed parametric modeling of $d(\cdot)$ the *comparison density* with e.g., shifted Legendre polynomials — more terms, more complex.

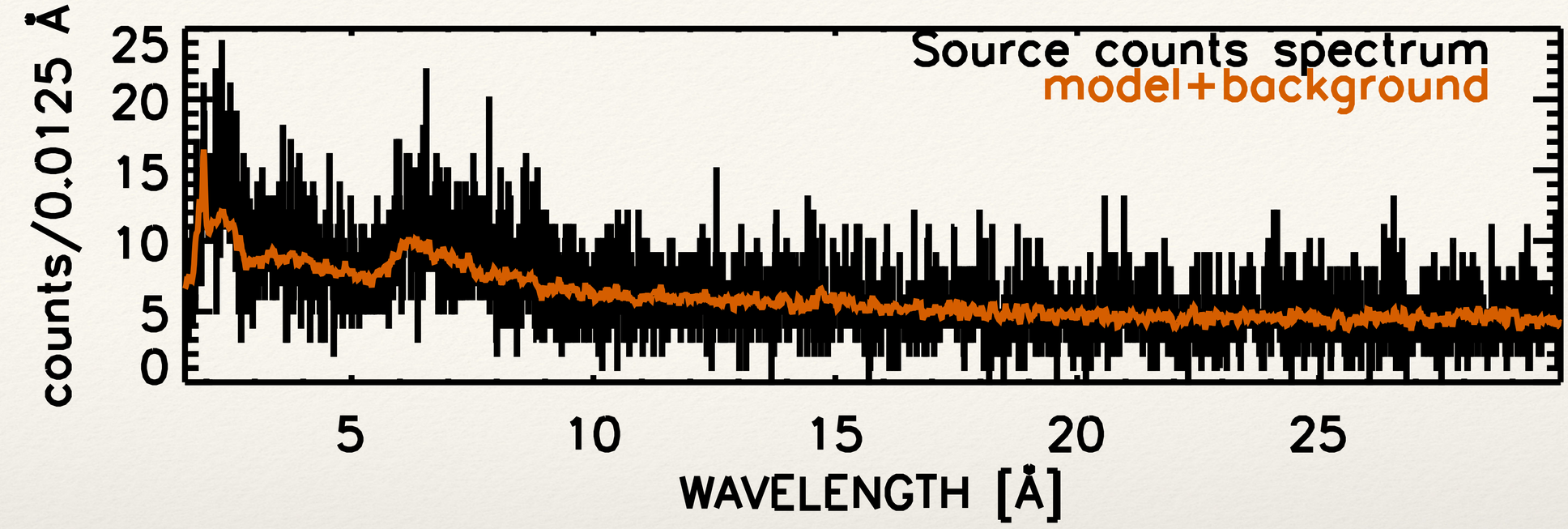
λ, E

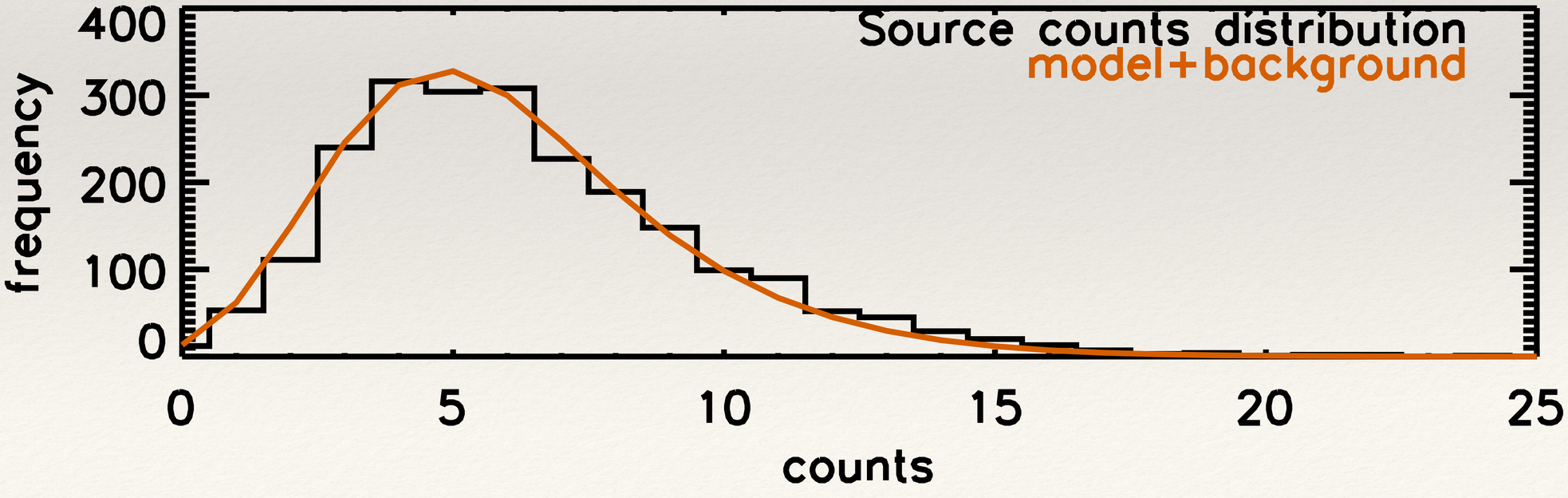
DETECTABILITY

When there are a lot of bins, there can be a lot of large fluctuations.

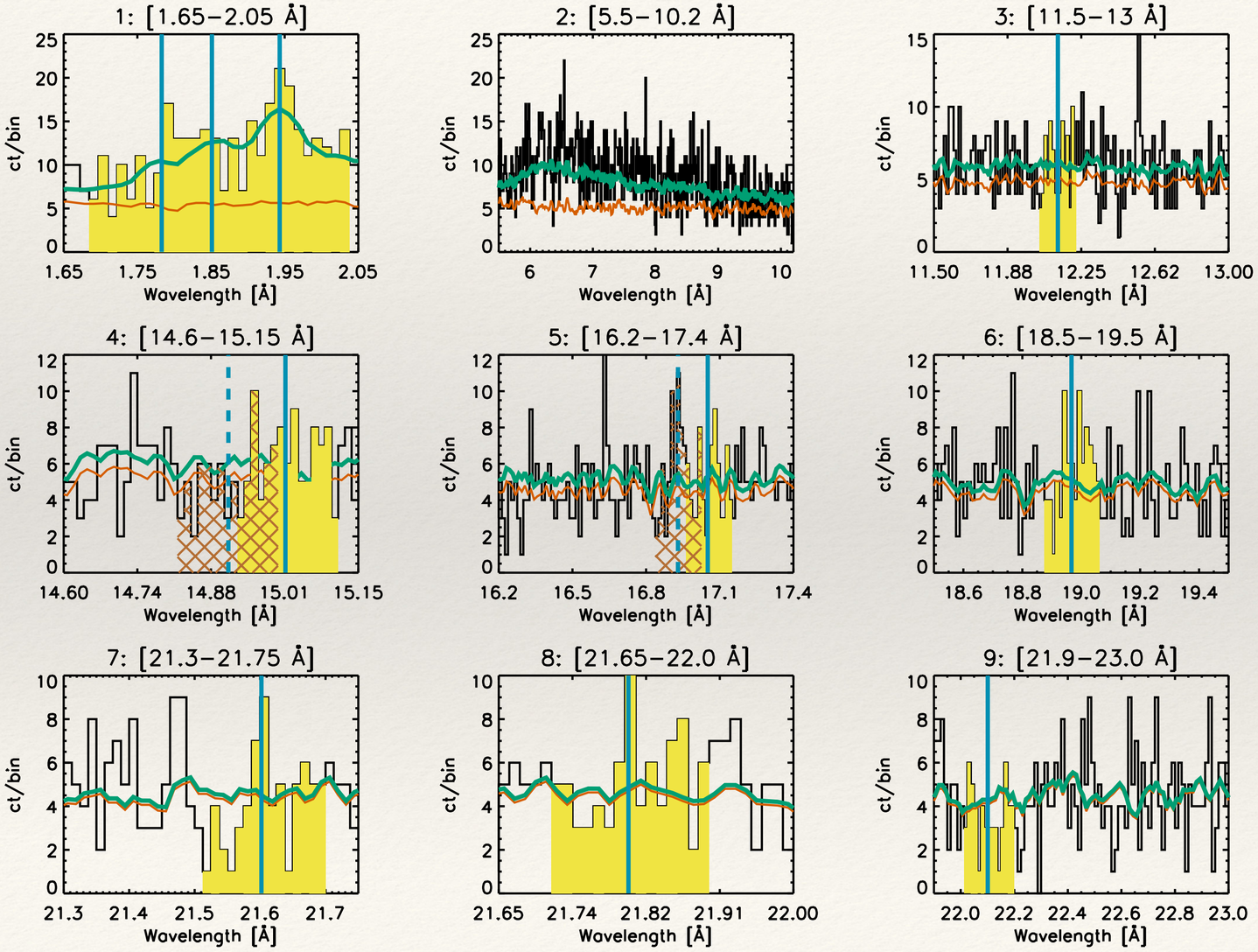
Top: HRC-S/LETG spectrum of RT Cru (black), with best-fit model (including background) in red. Question: is the model spectrum a fair representation of the data, or are there lines left unrecognized?

Middle: Distribution of binned counts (black) and expected distribution based on model (red). Yeah, nah.





RT Cru, upper limits via power



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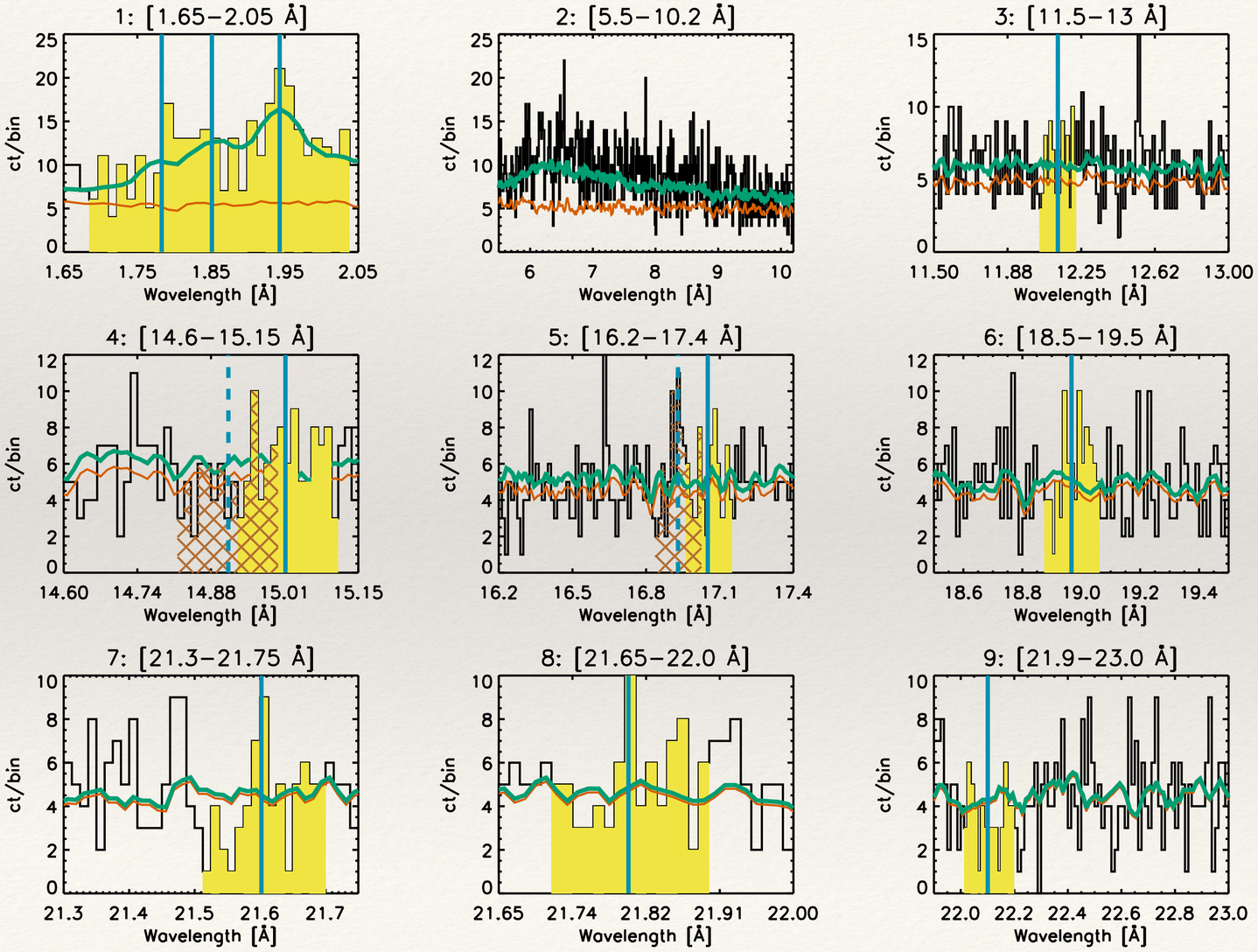

Regions of interest (W_r)	m	Bonferroni (Sidak)	K (Sidak)	Naive (Sidak)
W_1	3	0.0001 (0.0011)	0.0071 (0.0397)	0.0045 (0.0621)
W_2	3	1.0816e-18 (1.0817e-17)	2.7907e-15 (2.9976e-14)	3.3306e-15 (2.4980e-14)
W_3	0	1.0000 (1.0000)	1.0000 (1.0000)	1.0000 (1.0000)
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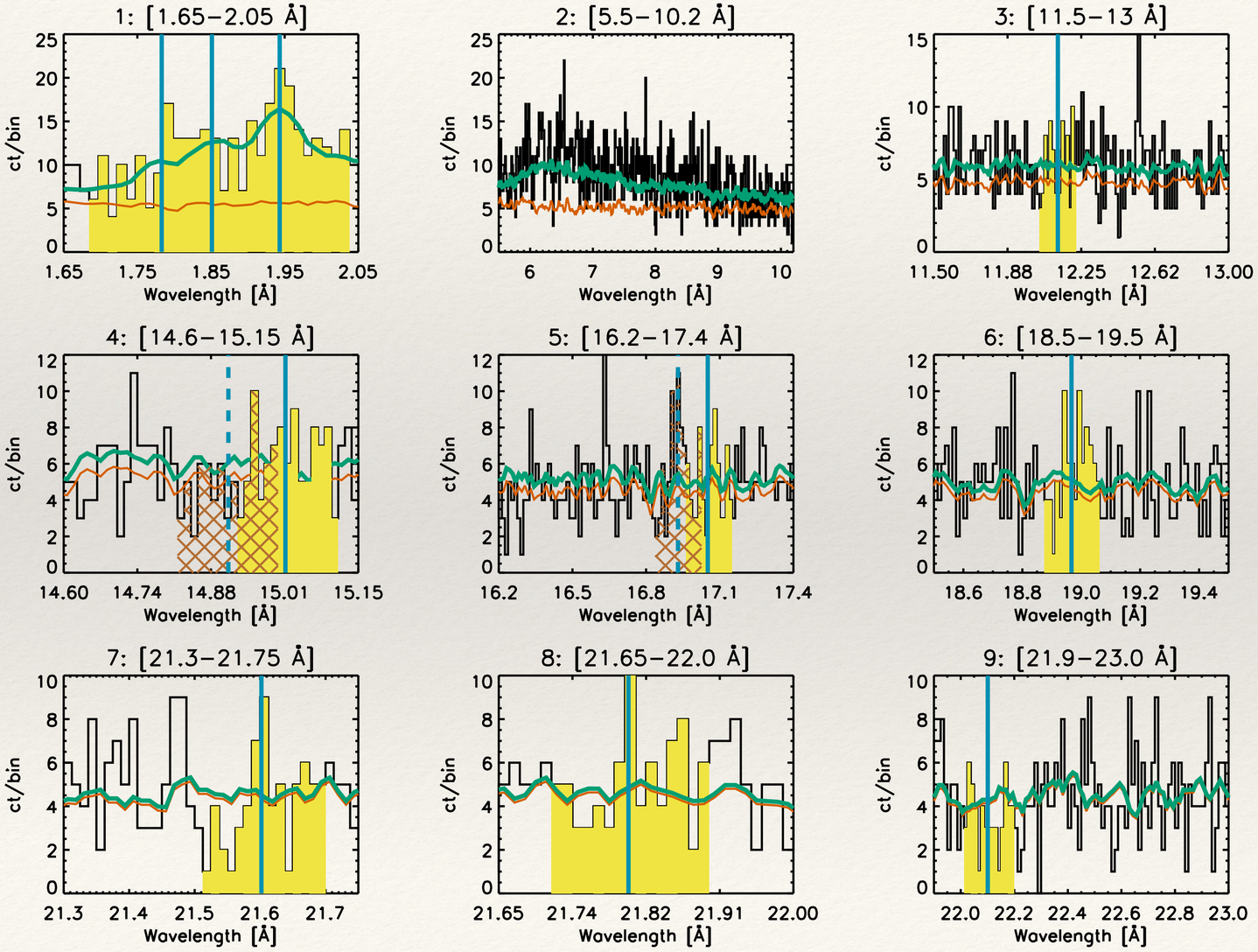
W_9	0	1.0000 (1.0000)	1.0000 (1.0000)	1.0000 (1.0000)

Testing for difference from background

RT Cru, upper limits via power



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Testing for lines at nominal locations

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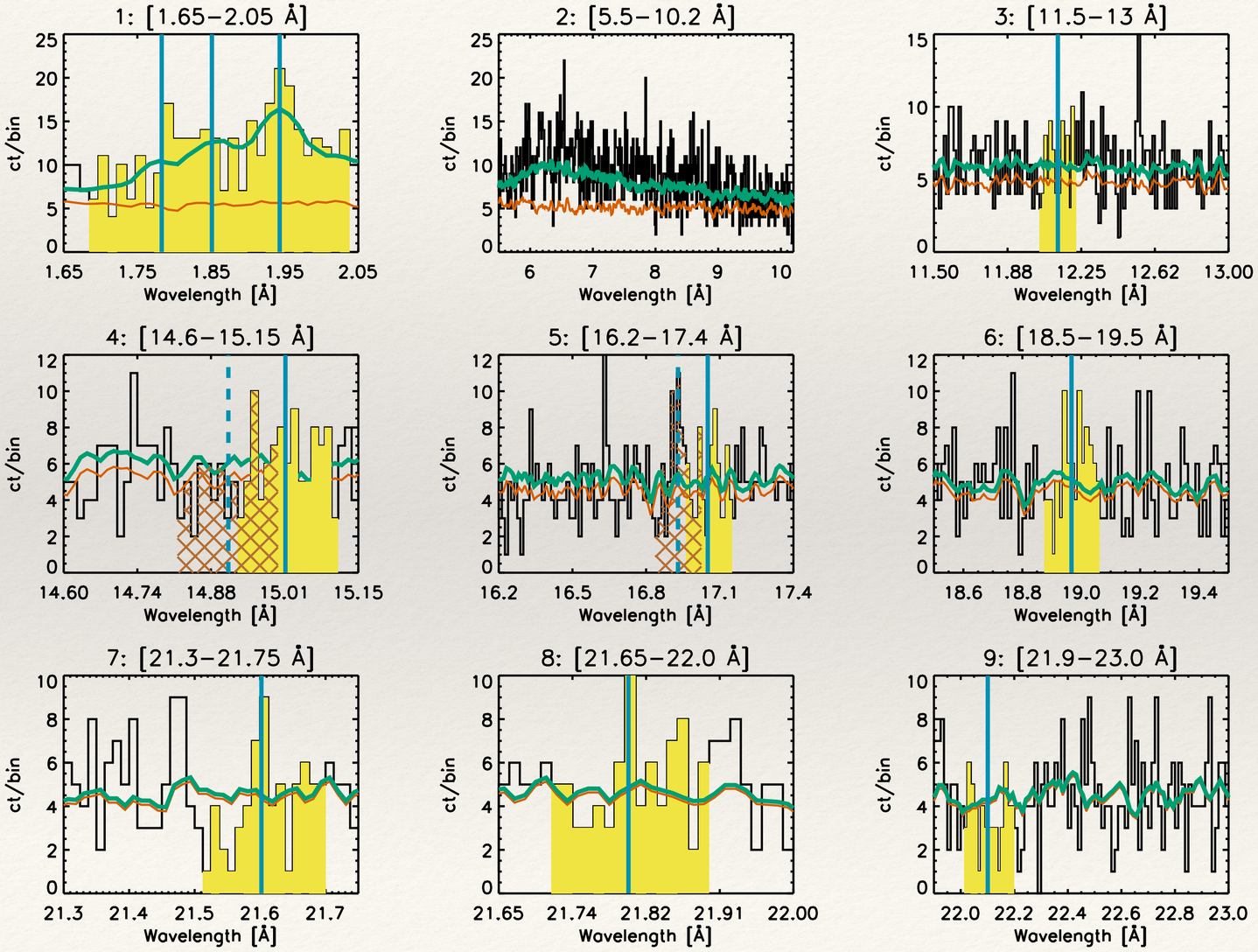

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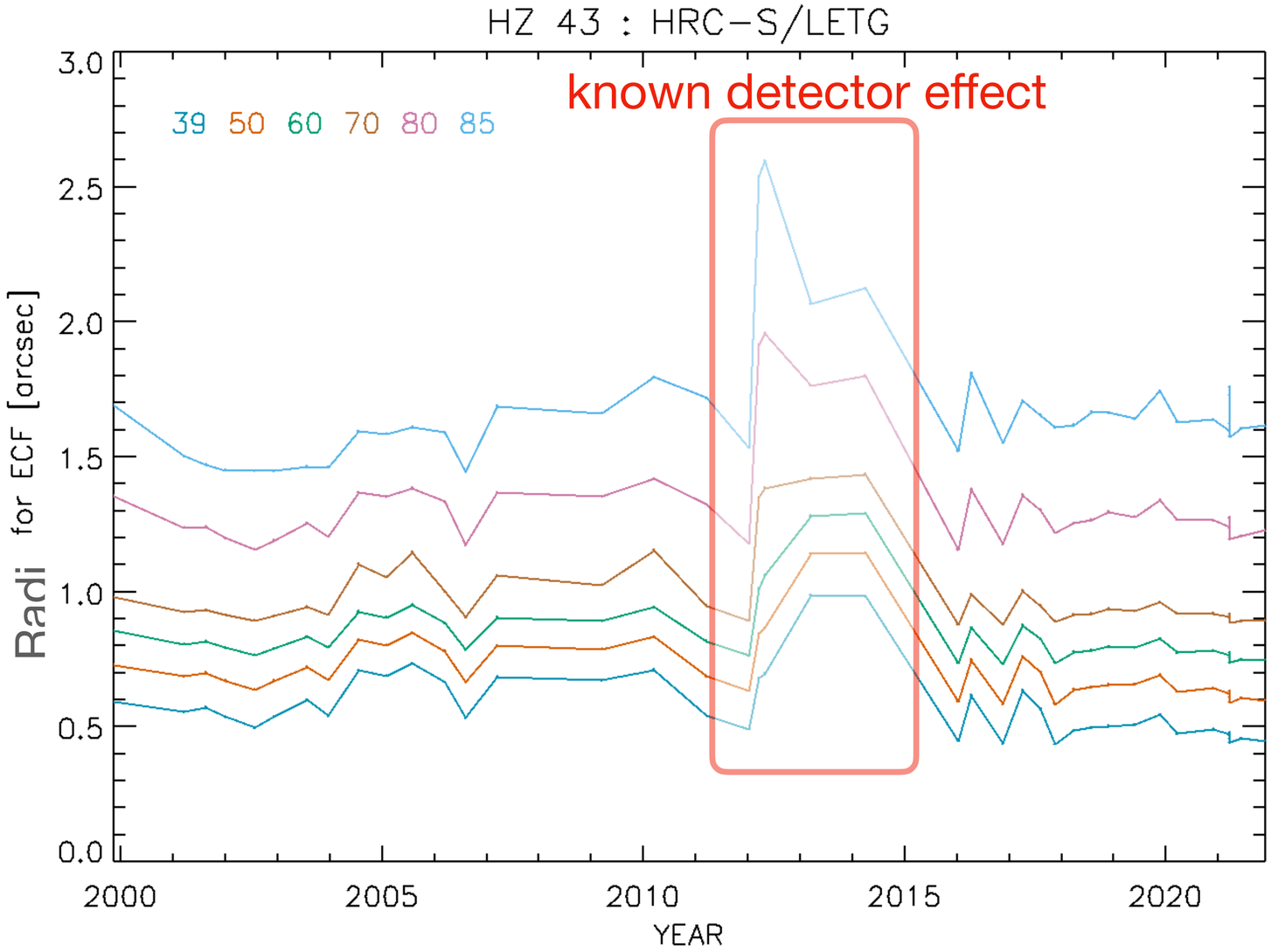
Setting upper limits to lines

Regions (W_r)	50% upper limits via LRT		90% upper limits via LRT	
	Local	Sidak adjusted	Local	Sidak adjusted
W_3	29.93	39.42	48.91	53.29
W_4	20.00	26.43	32.36	39.52
W_5	24.02	30.14	35.32	43.80
W_6	22.62	28.08	34.71	39.39
W_7	17.90	24.17	29.71	35.98
W_8	17.84	24.80	30.30	36.25
W_9	37.83	21.87	63.57	76.83

HRC degap: work in progress



The "known detector effect" is degap. The source position had drifted on to a part of the detector with less well-determined position corrections.

Raw positions are corrected to remove gaps.

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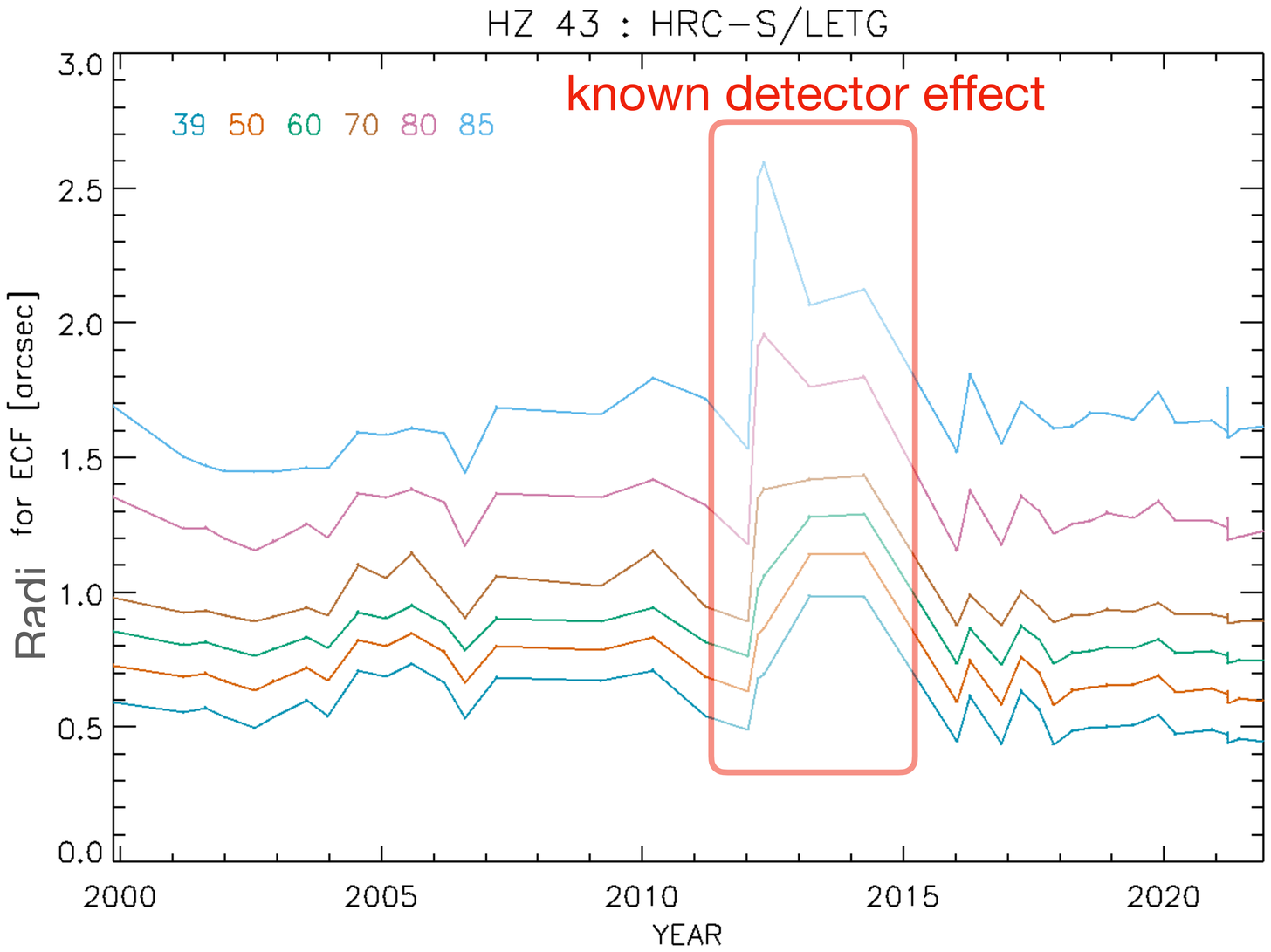

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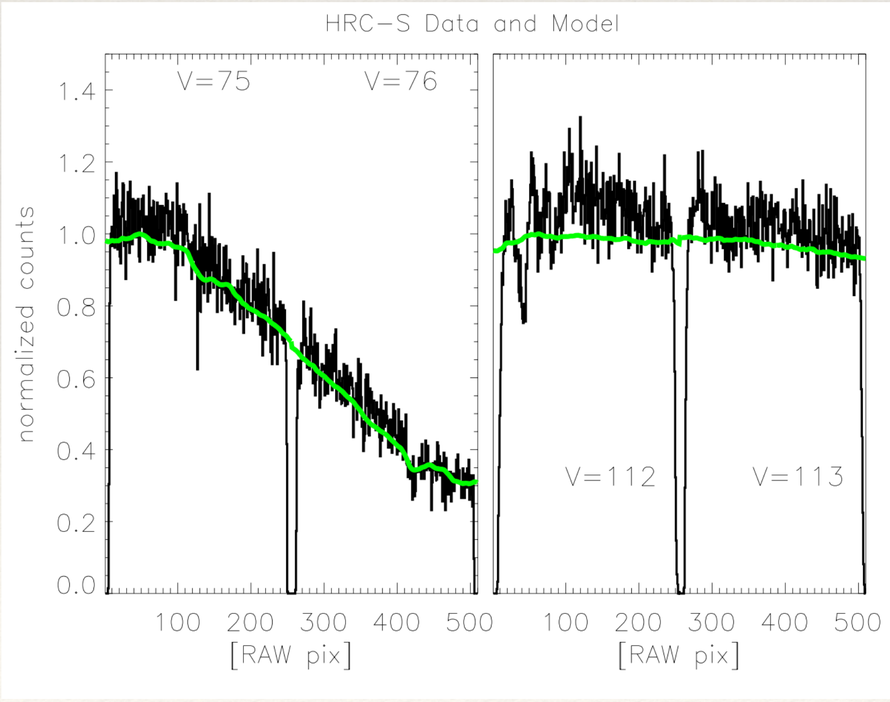

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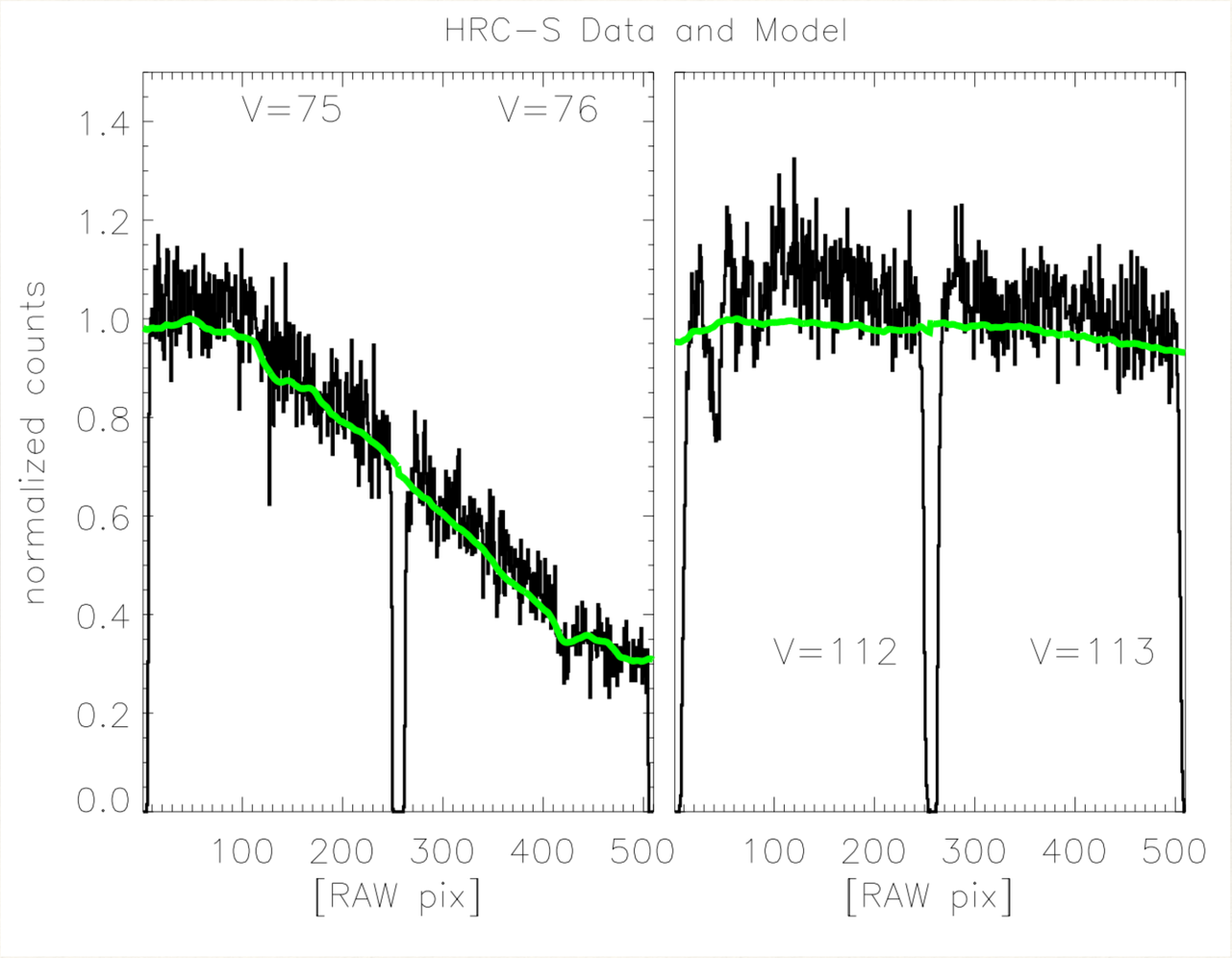

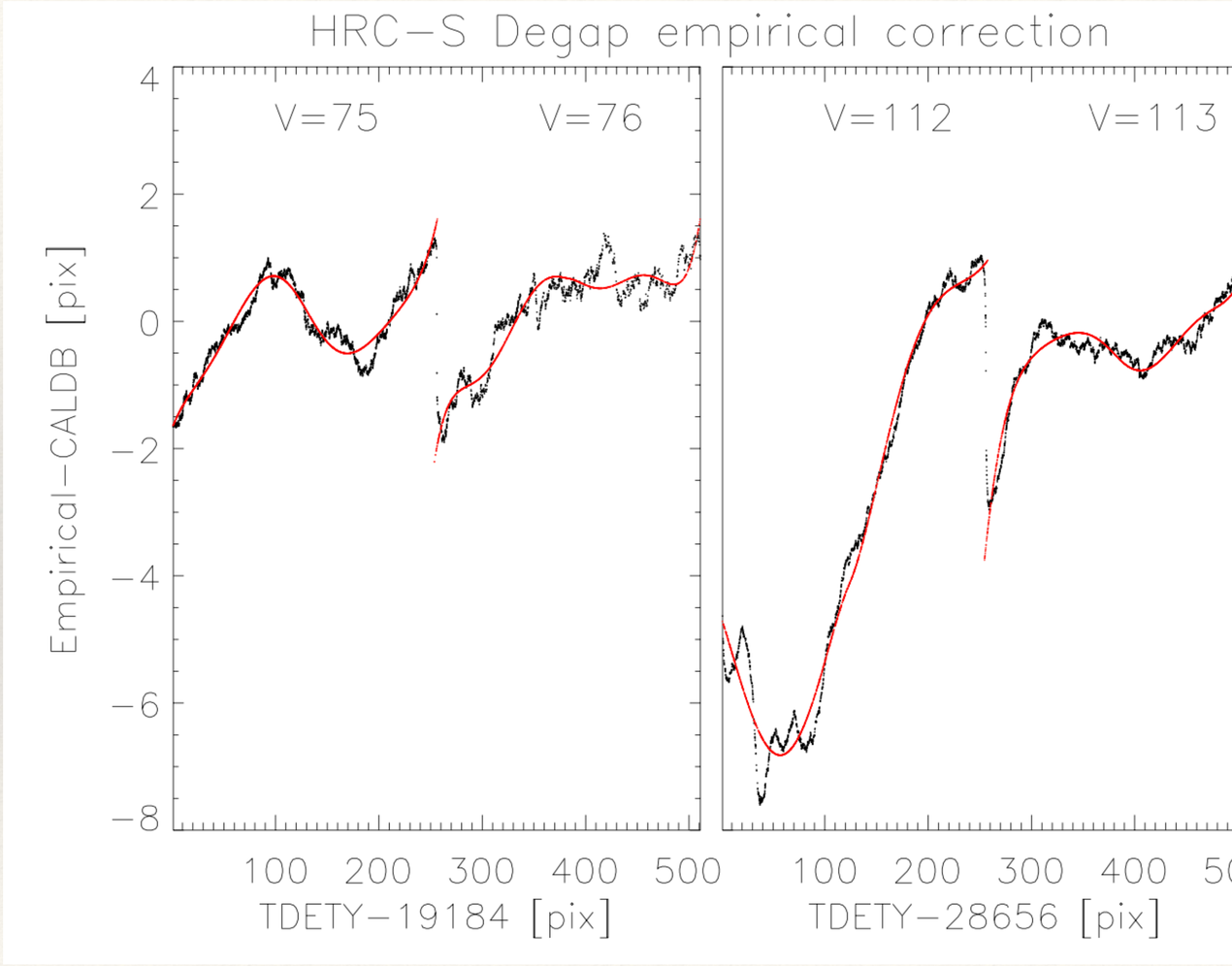

HRC degap: the plan

- Cross validate degap solutions
- Test for spatial variability (degap is assumed fixed along perpendicular direction)
- Test for temporal variability (suspected, but innocent until proven guilty)

Takeaways

- CalStats WG
  - New method to look for departures from expected spectral model based on smooth test for number of shifted Legendre polynomials
  - https://github.com/xiangyu2022/LPBkg
  - https://github.com/xiangyu2022/Symbiotic-Star-RT-Cru-Analysis
- Hi-Res WG
  - Crucial to know where the lines are expected to be
- Background WG
  - Tool to verify background models