On the reality of red/blue-shifted narrow lines in X-ray spectra

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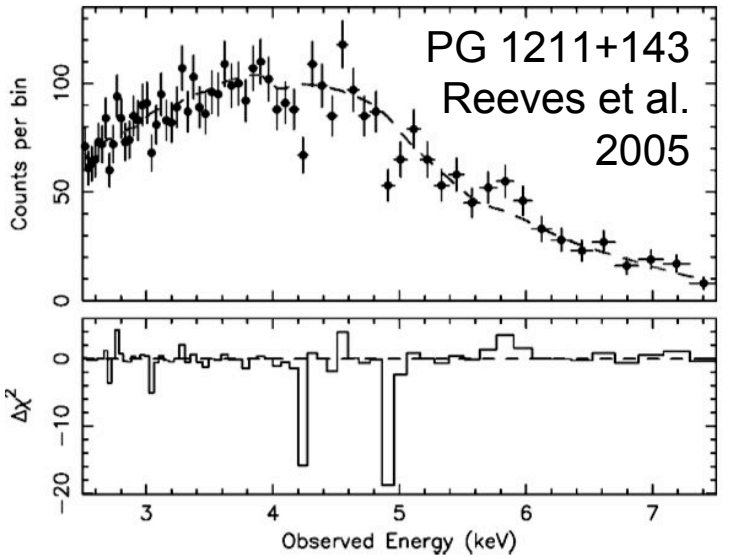
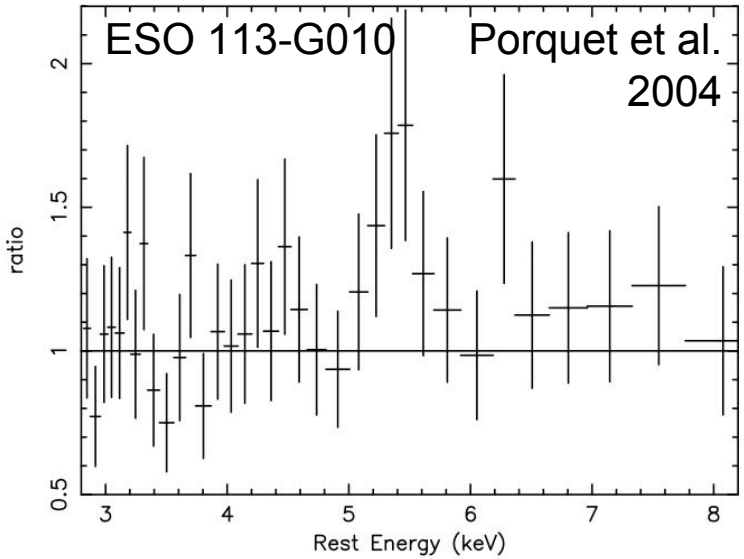
(based on Vaughan & Uttley 2008, MNRAS 390, 421)

Narrow red/blueshifted lines





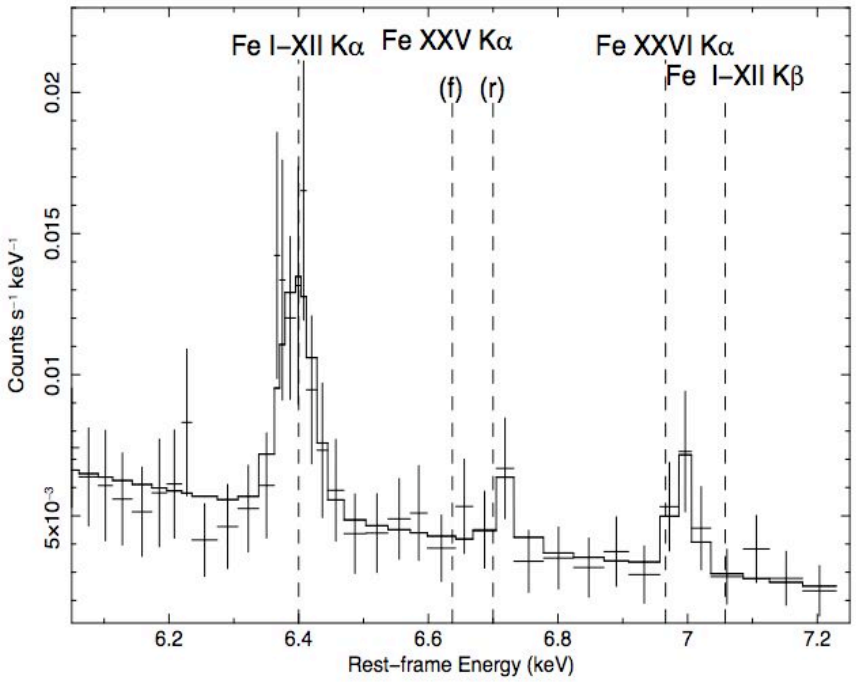
- Unresolved/marginally-resolved (σ < 0.1 keV) absorption/emission lines

- Appear at energies significantly red/blueshifted w.r.t known line energies (v > 0.05c)

$\Rightarrow$ If real features, would have important implications (fast outflows/inflows, emission hotspots)

Significance tests

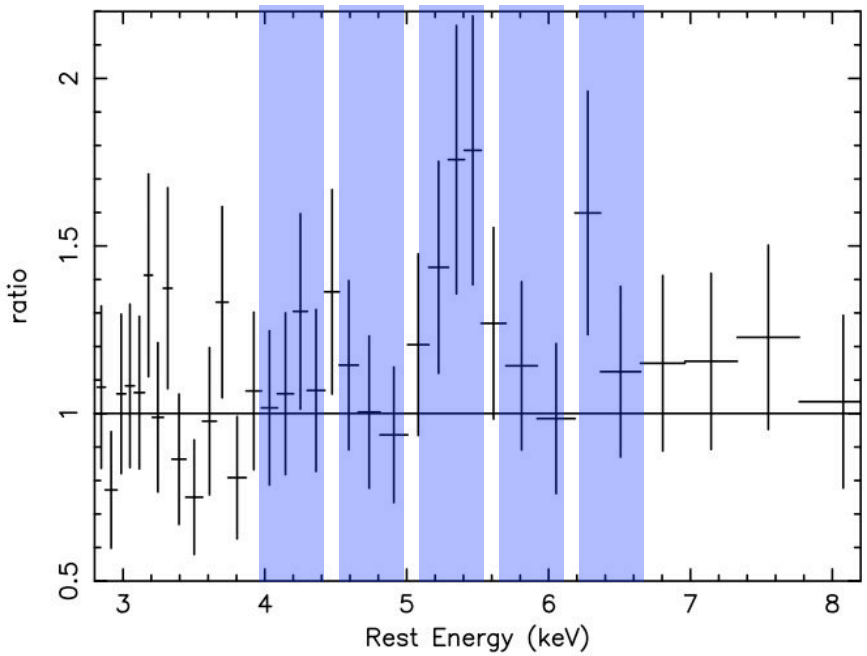
NGC 7213, Bianchi et al. 2008



Normal procedure: fit line with Gaussian, measure $\Delta\chi^2$ w.r.t. continuum model and compare with number of additional free parameters.

This is fine for ‘single trial’ measurements where we know which energies to look at a priori - what about arbitrary energies?

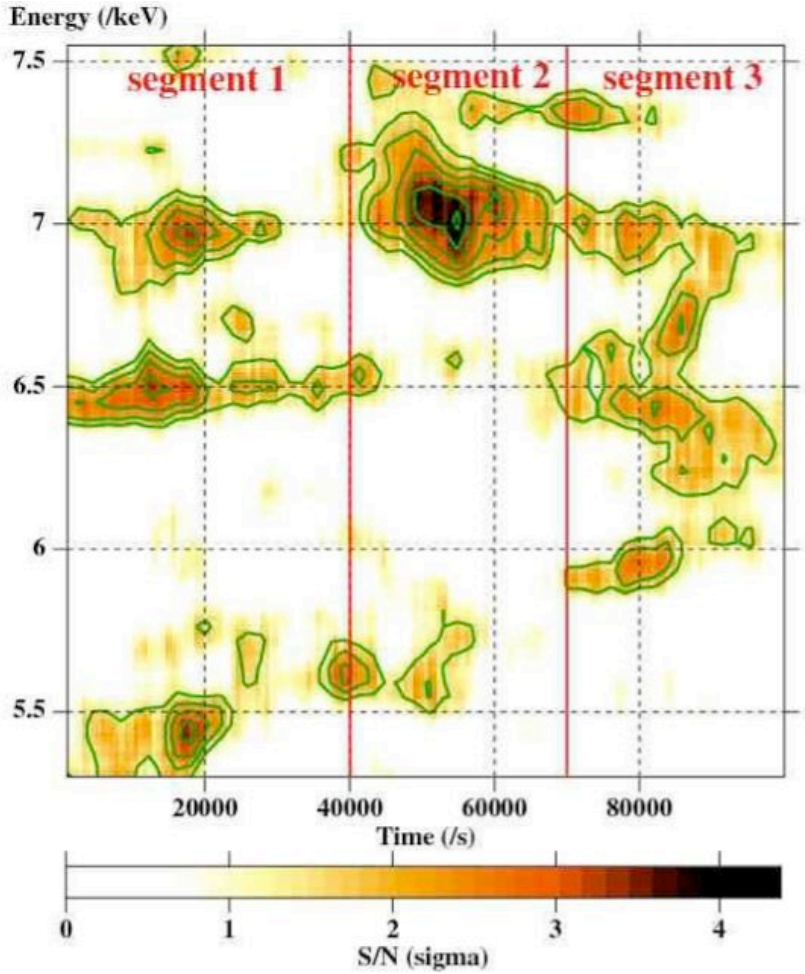
Number of trials



For narrow lines of arbitrary energy, we cannot simply include energy as another free parameter, since number of trials depends on number of independent energy bins searched over

Can simulate (e.g. see Porquet et al. 2004), or use ‘quick & dirty’ method’ and calculate p^N where p is the number of trial energy bins (‘Bonferroni correction’)

Time selection of data



(ESO 113-G010 Porquet et al. 2008)

- Time selections of subsets of data also add to the number of trials
- Normally we can multiply by number of segments
- But great care must be taken when we make a posteriori selections of segments based on how the data appears to us

Hidden trials - publication bias

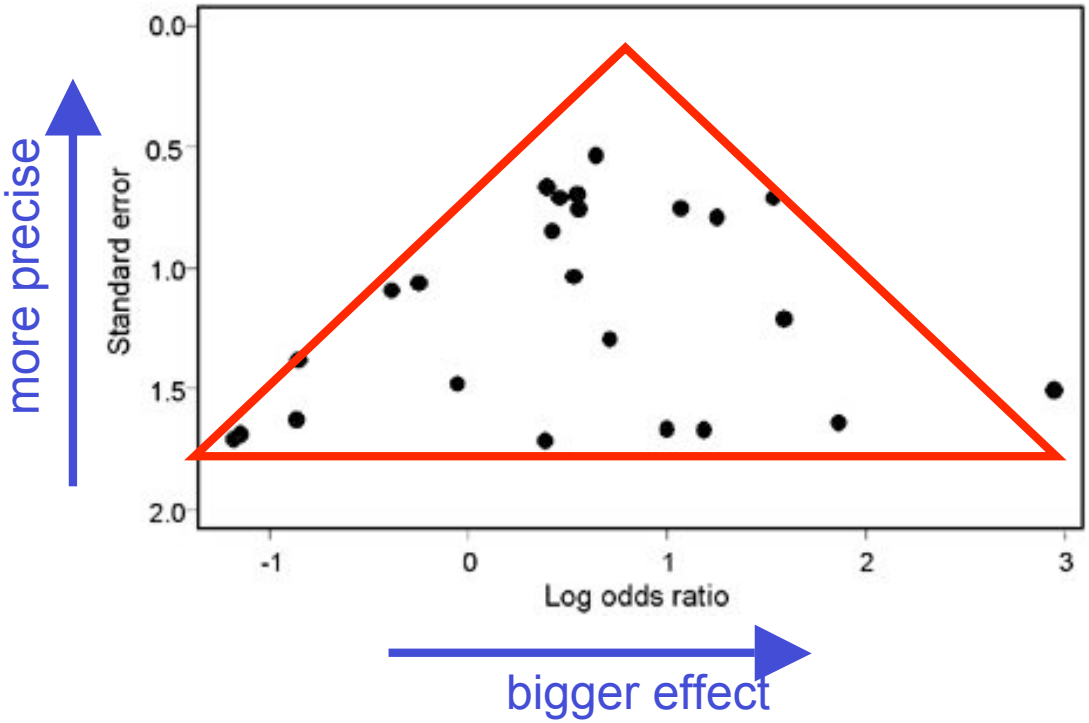
There are very many X-ray observations (100s) which have been searched, either purposefully or subconsciously, for unusual features. These are the 'hidden trials'.

"*Publication bias occurs when the publication of research results depends on their nature and direction*." (Dickersin 1990; JAMA)

"…*notice the events where they are fulfilled, but where they fail, though this happens much more often, neglect and pass them by*."
(Francis Bacon, *Novum Organum*, 1620)

How to search for publication bias

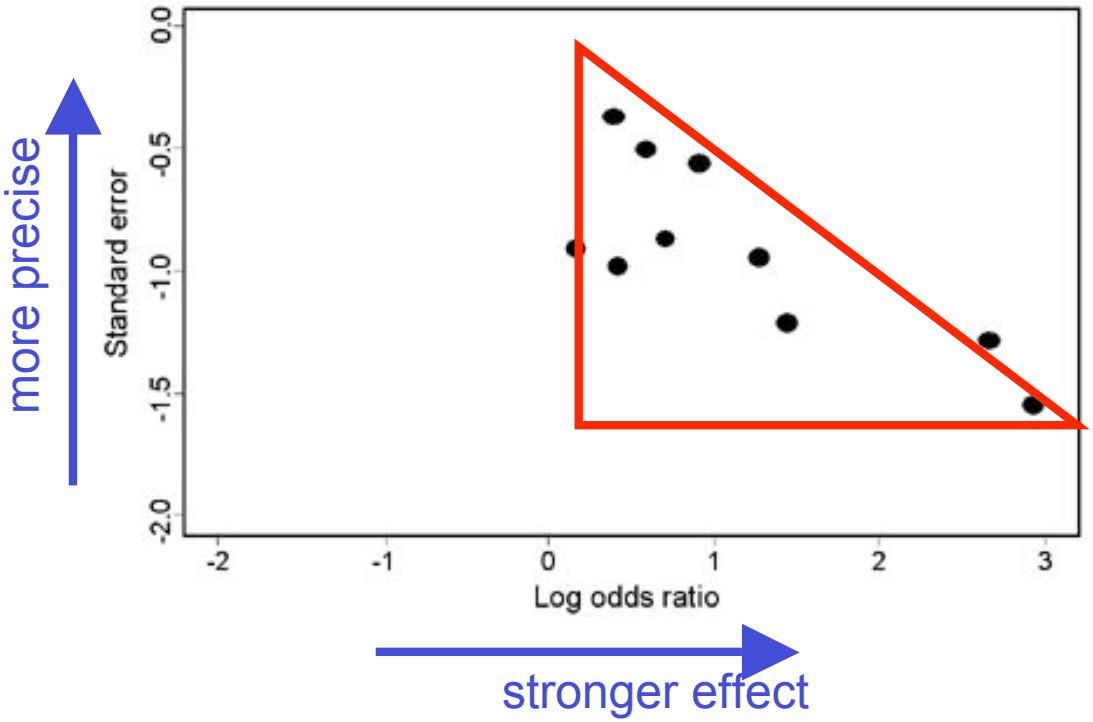
Funnel plots are used in ‘meta-analyses’ of medical trial results to search for publication bias



If an effect is real and there is no publication bias, results will cluster around the real effect and favour neither the statistically larger nor smaller effects

How to search for publication bias

If publication bias is present, publication of stronger effects is favoured and the weaker effects (or non-detections) are filtered out of the published record. Effect strength becomes anti-correlated with precision.



A funnel plot for astronomers

Effect strength = strength of signal, e.g. line EW

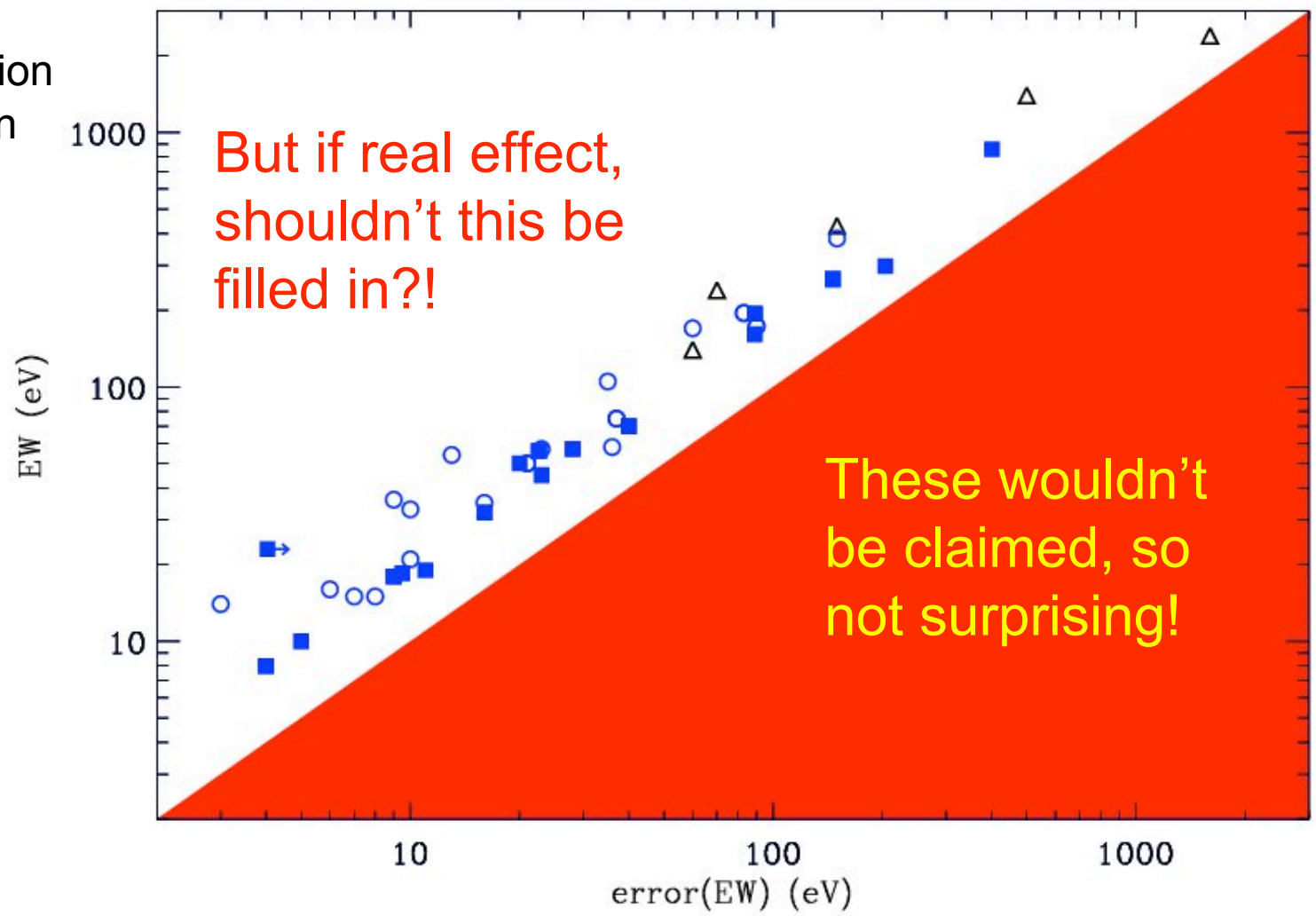
Precision = error on signal, e.g. error on EW

To test for evidence of publication bias, search literature for published narrow red/blueshifted lines:

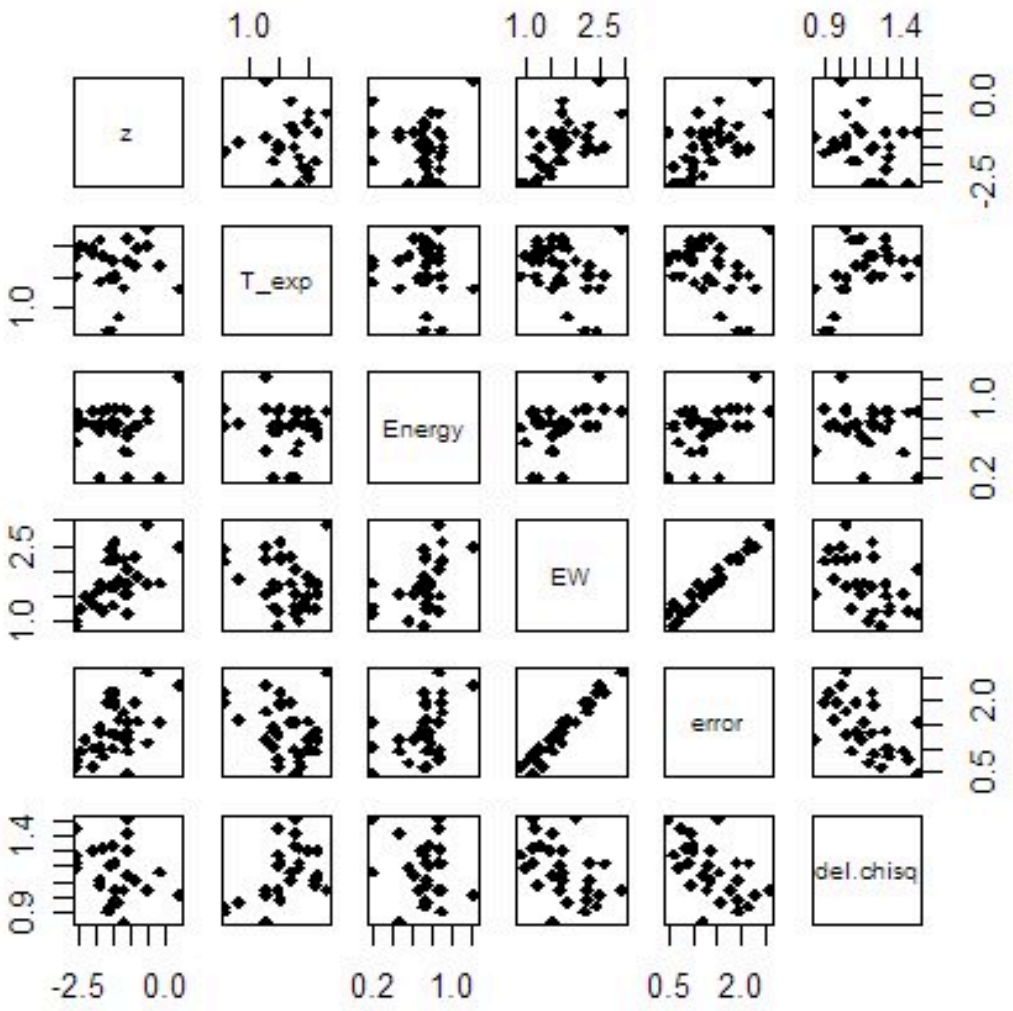
38 lines, 36 have quoted EW and its error (almost always single trial 90% confidence)

Results

△ X-BALs
○ Absorption
■ Emission



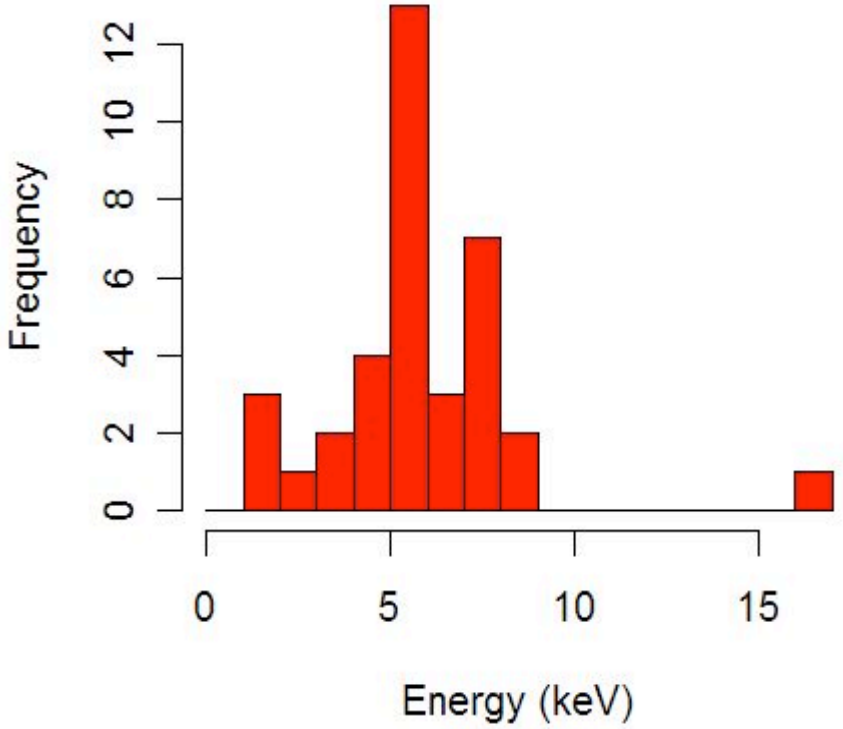
Confounding factors?

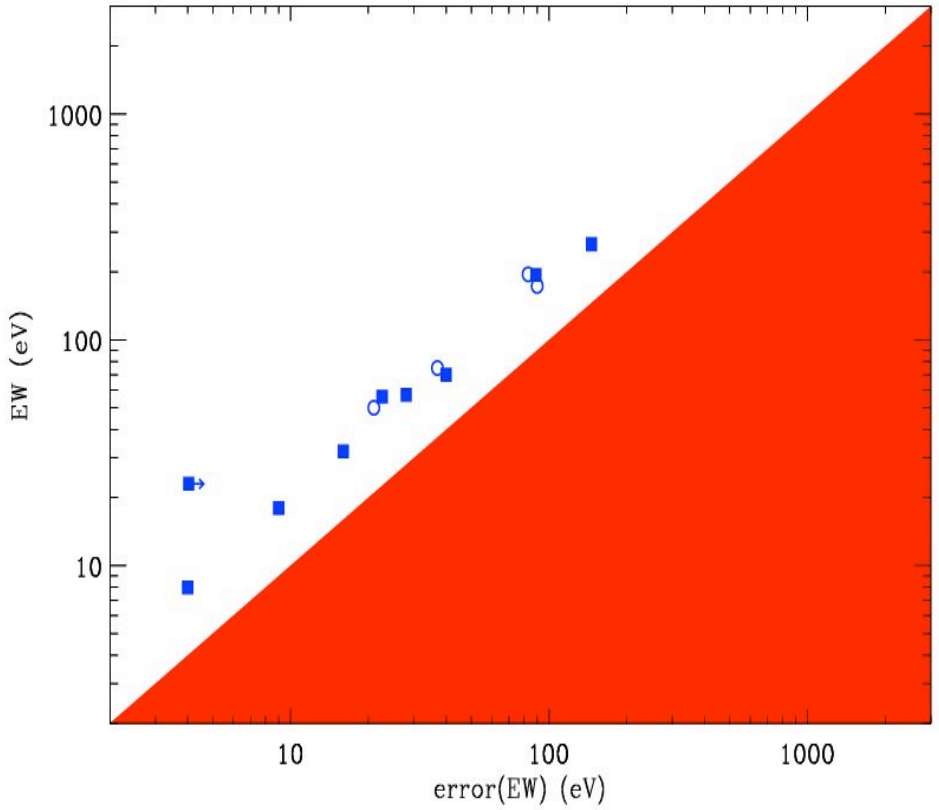


Line energies

Excess of published detections around 5-6 keV - more plausible signals lost in the noise of spurious extreme cases?

No evidence for this - could be further publication-bias effect?





Absorption vs. emission lines

- Situation looks better for absorption lines than emission lines (systematically higher EW/error) - also seen in the same spectra and repeat observations (e.g. PG 1211+143), but **not** at same energies

- BAL QSOs are unusual systems, also all faint so not surprising that line EW is large and error is too, these features would appear to be real.

Conclusions

- There is strong evidence for publication bias in red/blueshifted narrow line detections
- Some reasons to suspect at least some absorption lines are real (+BAL QSO lines), but evidence for emission lines is weak
- If narrow emission lines exist, they are likely hiding with EW<30 eV
- Simple method offers a powerful tool to test reality of lines - please populate the plot!