Abstract

Magnetars (Soft Gamma-ray Repeaters and Anomalous X-ray Pulsars) have been very exciting to research as of late, with their many and varied high-energy phenomena. They promise, with extreme magnetic, electrodynamic, energy, density and gravitational properties, to be ideal natural laboratories for unlocking the secrets of fundamental physics. Using direct measurements of photoelectric absorption edges, I derive the intrinsic spectra for the Anomalous Xray Pulsars. Particularly for the brightest source, 4U0142+61, the correction is highly significant, and thus may alter the interpretation of other recent results for this source. To be emphasised, is that this is an empirical method with the minimum of assumptions, as is appropriate for these beguiling sources, the behaviour of which has mystifies astronomers for over a decade.

Extinction Columns and Intrinsic Spectra of Anomalous X-ray Pulsars.

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Outline

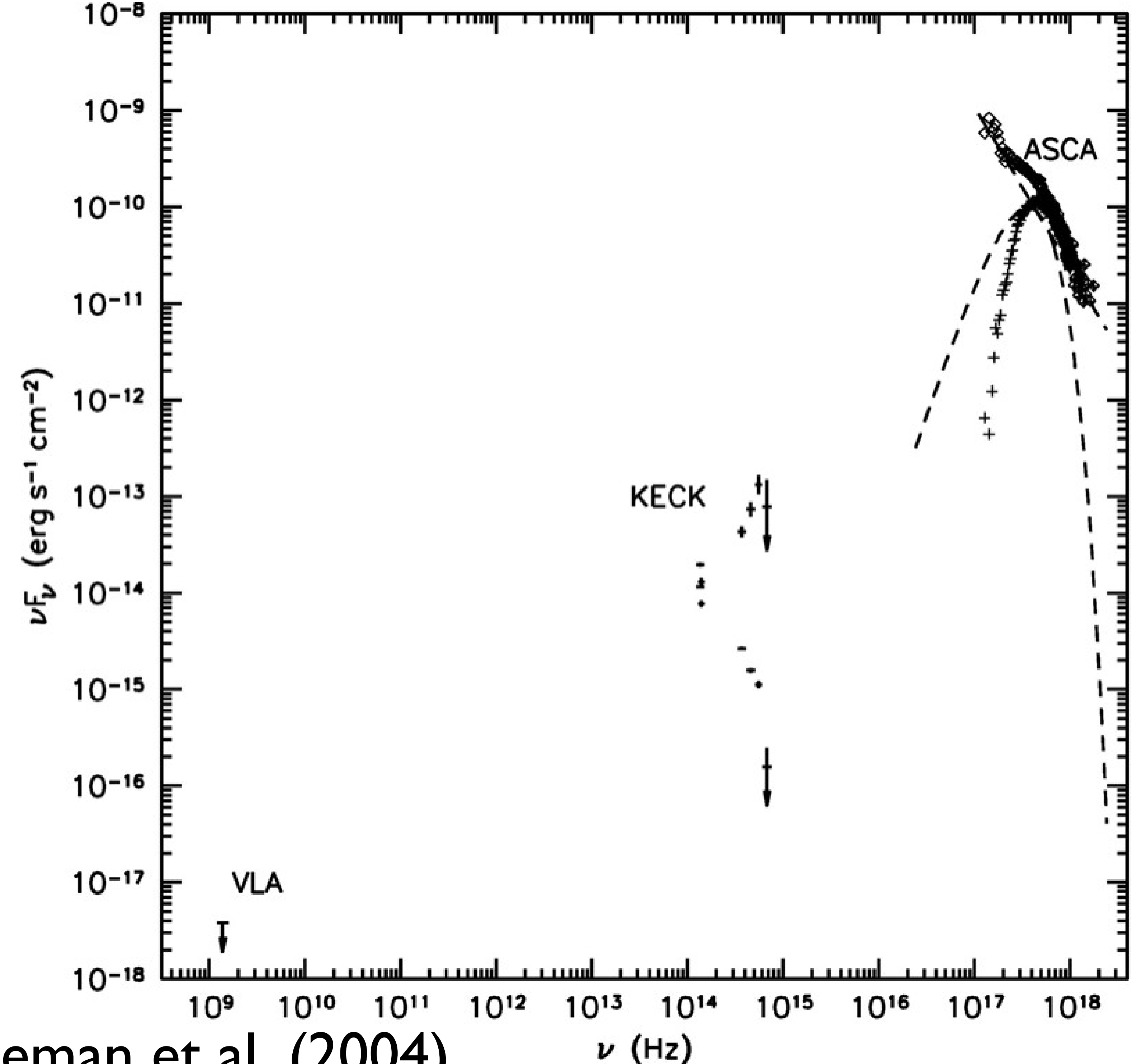
- Introduction: why extinction is important and why the standard determination might be wrong
- Method: how I measured new columns from high-resolution XMM/RGS spectra
- Results: three consistent columns, one very different
- Implications: new SED

Problem of Extinction

- Extinction from gas and dust can profoundly affect the observed spectrum, optical to soft X-rays
- Extinction is energy-dependent, so the shape of the spectrum is changed
- In order to find the intrinsic spectrum, extinction needs to be indendently measured.

Extinction

- All magnetars lie in Galactic Plain, except one in SMC and one in LMC: high column densities
- Extinction found by assuming X-ray spectrum is blackbody plus power-law



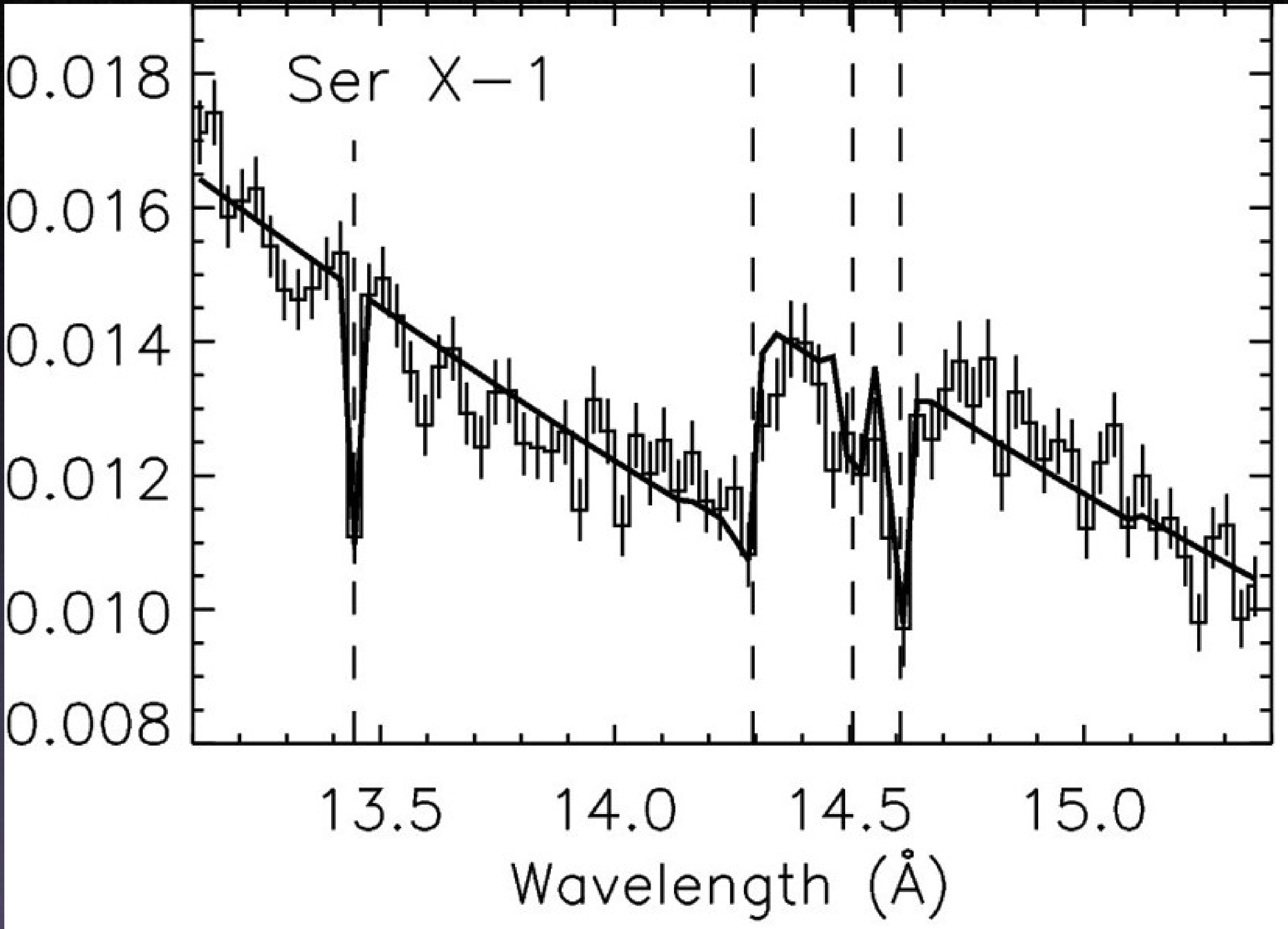
Hulleman et al. (2004)

Extinction??

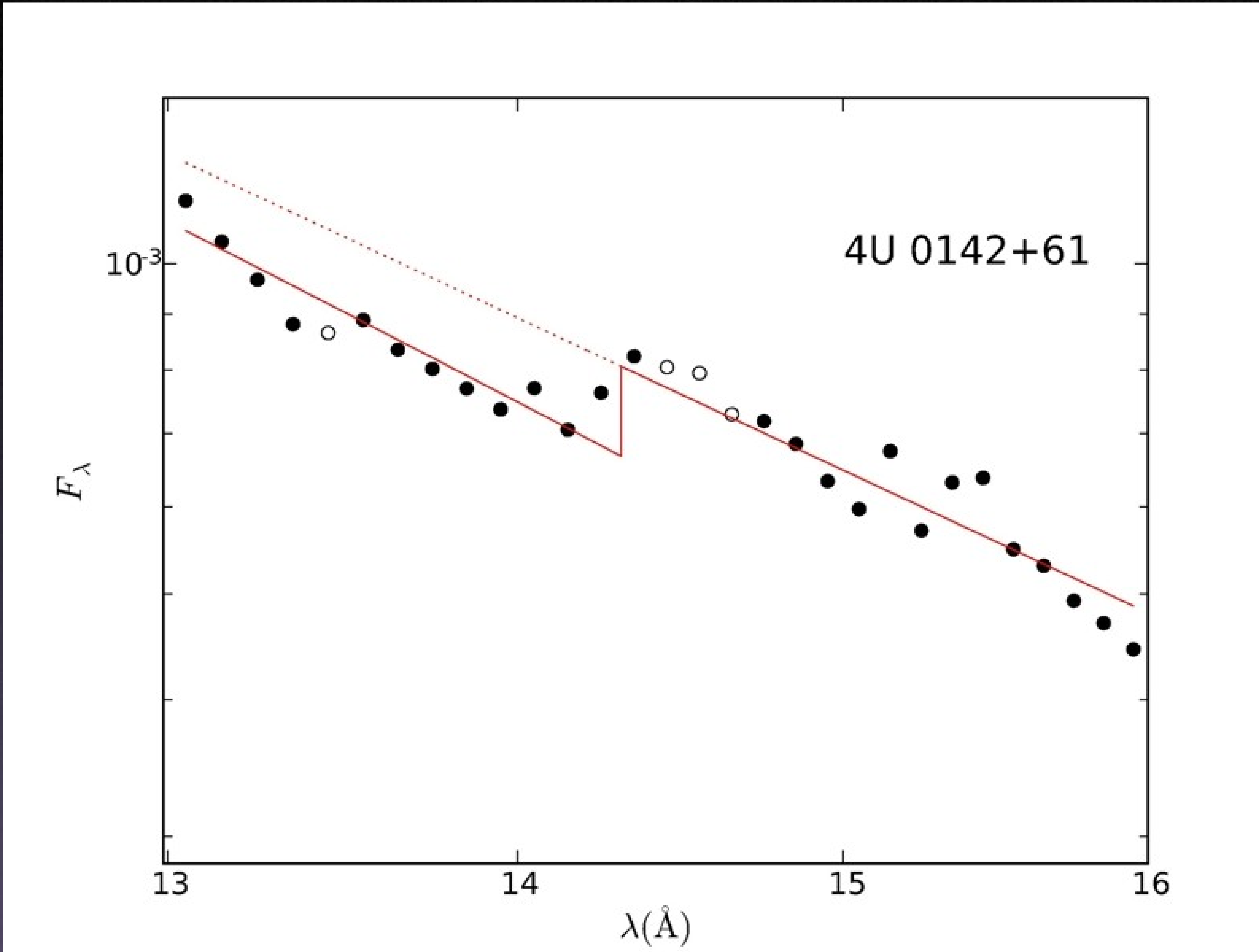
- All magnetars lie in Galactic Plain, except one in SMC and one in LMC: high column densities
- Extinction found by assuming X-ray spectrum is blackbody plus power-law
- Power-law sensitive to >2keV, but dominates at <500eV. Extinction is strong <500eV, and profoundly affects spectrum.
- Power-law over-predicts optical

Method

- Use XMM/RGS datasets for each AXP
- O, Fe-L, Ne, Mg and Si in RGS sensitivity range
- Chose small spectral region around each edge
- Fit for power-law with edge
- Use latest data:
  - edge energies
  - edge structure, etc.



Neon edge: Juett et al. (2005, in prep)



4U 0142+61
10^{-3}
F_λ
13
14
15
16
$\lambda(\text{Å})$

Reddening

- New values of elemental columns can be used to estimate reddening, since we measure elements in dust directly (Fe, Mg, Si)
- A mapping from elemental columns to dust does not exist, but can still use Predehl & Schmitt's result (this is the best we can do)
- This approach does not depend on assumed hydrogen column
- Reliable results at least for relative reddening.

Results

Column densities found for each AXP

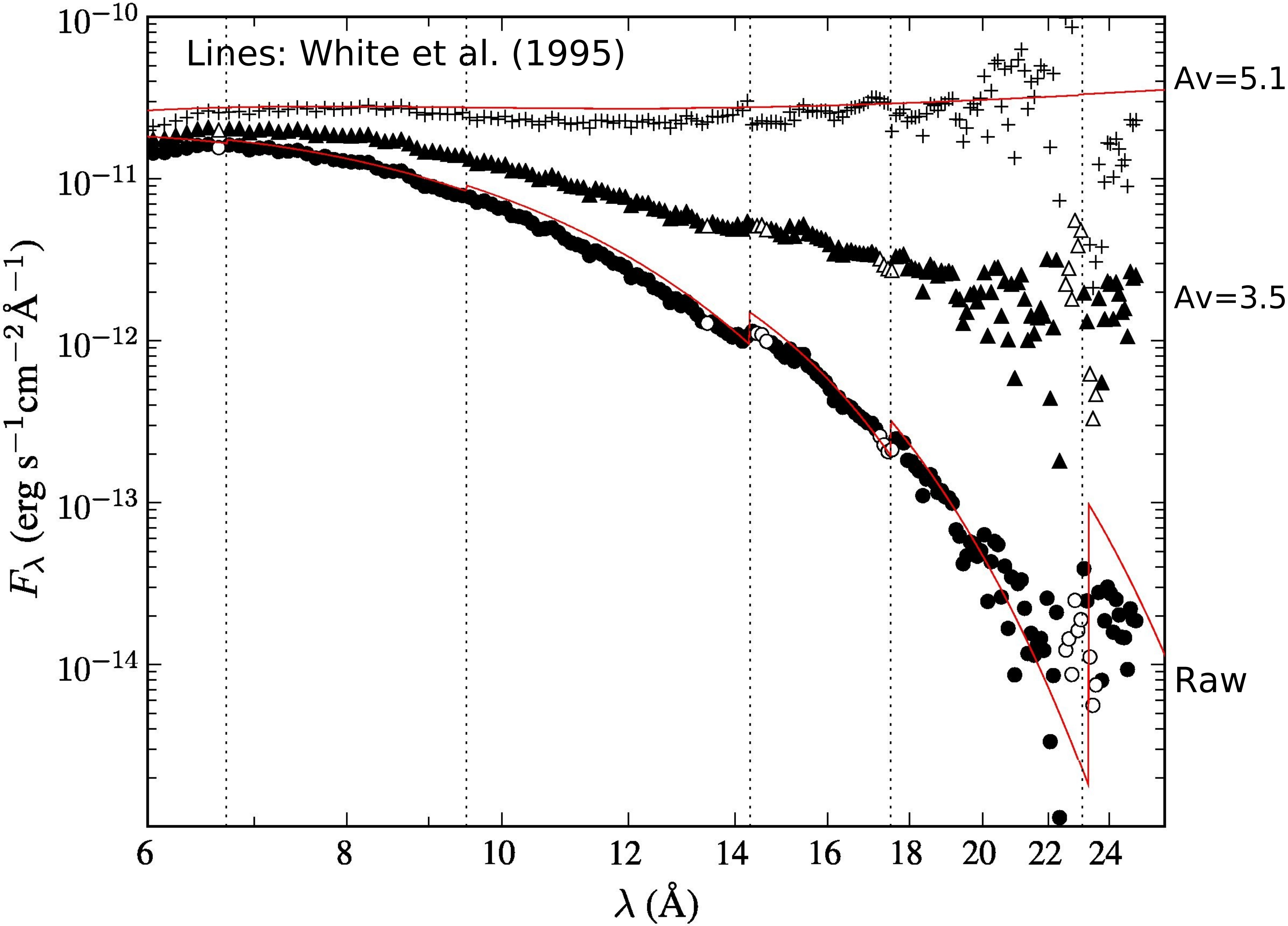
AXP	O K (10^{17} cm^{-2})	Fe L[a] (10^{17} cm^{-2})	Ne K (10^{17} cm^{-2})	Mg K (10^{17} cm^{-2})	Si K[a] (10^{17} cm^{-2})
4U 0142+61	28.8 ± 4.5	0.7 ± 1.4	5.3 ± 1.3	2.2 ± 0.5	2.0 ± 2.7
1E 1048.1−5937	···	···	7.1 ± 7	2.7 ± 2.4	11 ± 7
1E 2259+589	···	13 ± 6	8.5 ± 4	3.6 ± 1.4	0.6 ± 3.6
1RXS J170849.0−400910	···	···	15 ± 5	2.9 ± 1.8	2 ± 5

New extinction estimates

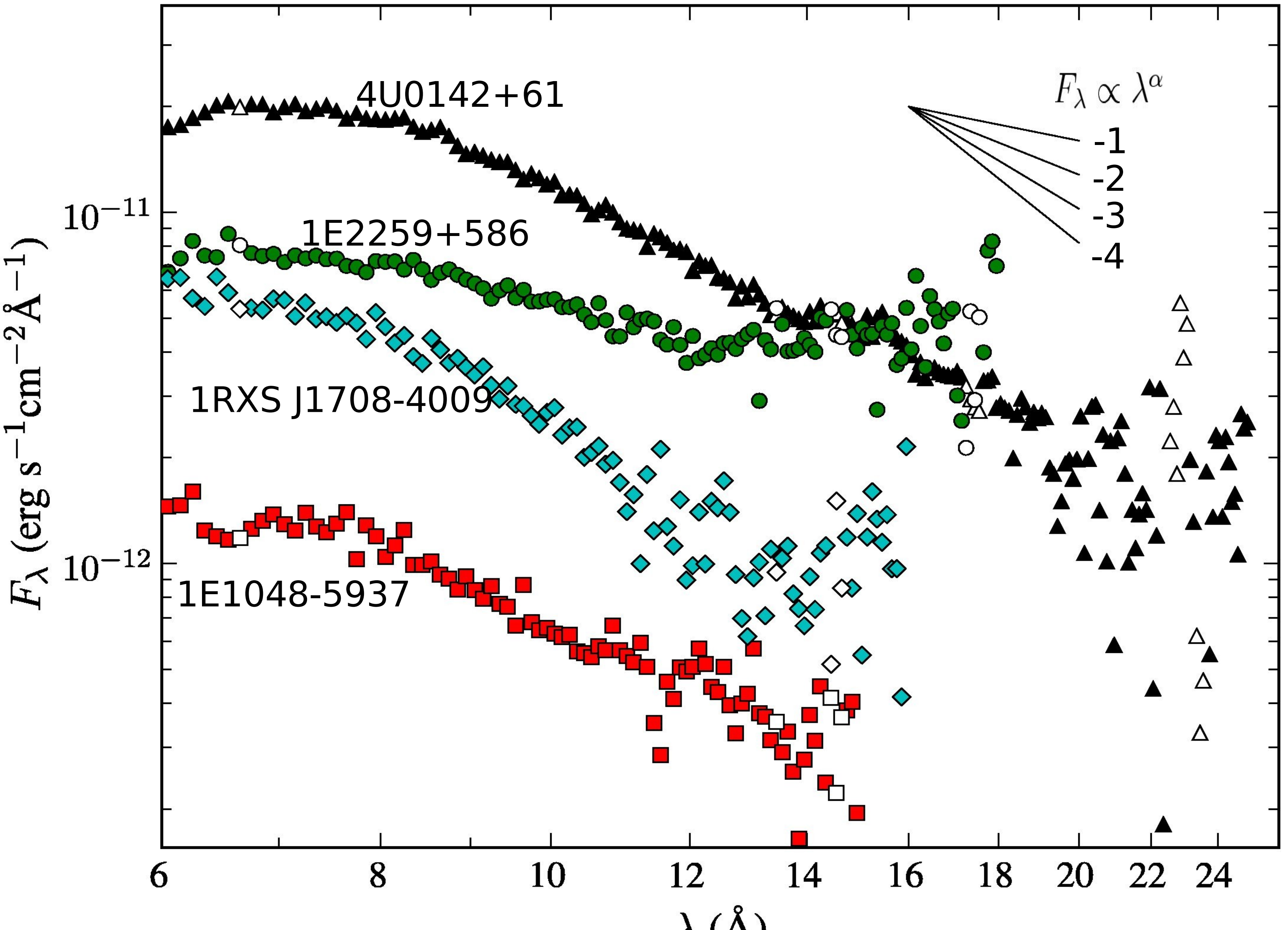
Inferred Hydrogen column densities and visual reddenings

AXP	$N_{\rm H}$(O K)	$N_{\rm H}$(Ne K)	$N_{\rm H}$(Mg K)	$\langle N_{\rm H} \rangle$	$N_{\rm H,lit.}$	A_V
Abundance[a]	4.6×10^{-4}	6.9×10^{-5}	3.4×10^{-5}			
4U 0142+61	6.0 ± 0.9	7.7 ± 1.9	6.5 ± 1.5	6.4 ± 0.7	9.1	3.5 ± 0.4
1E 1048.1−5937	...	10.3 ± 10	7.9 ± 7	8.7 ± 5.7	10	4.9 ± 3.2
1E 2259+589	...	12.3 ± 5.8	10.6 ± 4.1	11.2 ± 3.3	11	6.3 ± 1.8
1RXS J170849.0−400910	...	21 ± 7	9 ± 6	13.8 ± 4	14	7.7 ± 2.2

De-extinction: 4U0142+61

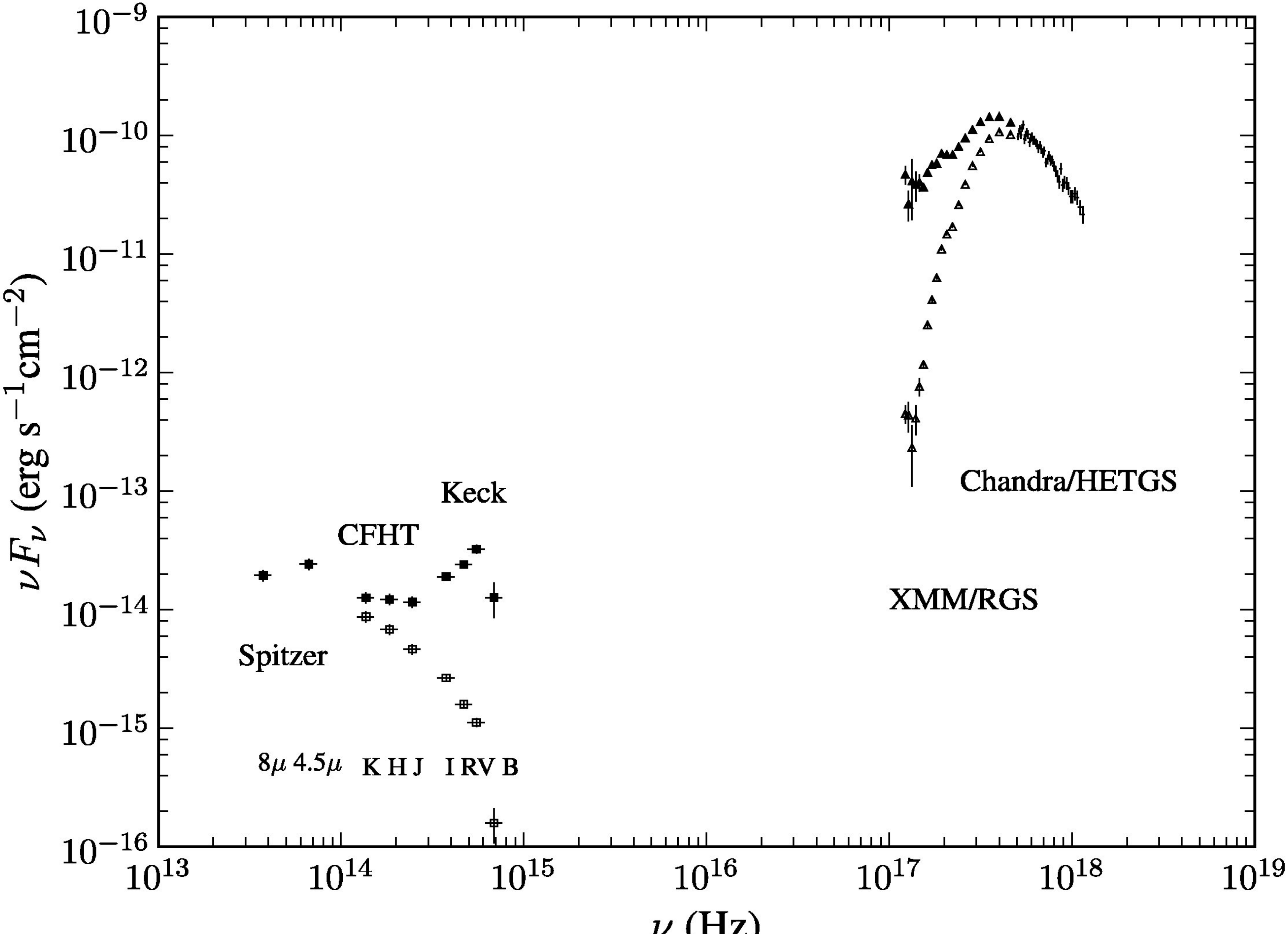


New spectra



4U0142+61
1E2259+586
1RXS J1708-4009
1E1048-5937
$F_\lambda \propto \lambda^\alpha$
-1
-2
-3
-4
10^{-11}
10^{-12}
F_λ (erg s^{-1}cm^{-2}Å^{-1})
6
8
10
12
14
16
18
20
22
24
λ (Å)

SED: 4U0142+61



Conclusions

- It is possible to measure extinction for AXPs, without assuming an intrinsic spectrum first
- We find column densities consistent with the old method for thee objects, but 1.4 times smaller for 4U0142+61
- The derived spectra show no continuation of the power-laws from the ~10keV range
- 4U0142+61's spectrum show a hint of a feature near 13A.