An unconventional approach to use high-resolution spectra to distinguish between variability in emission and absorption

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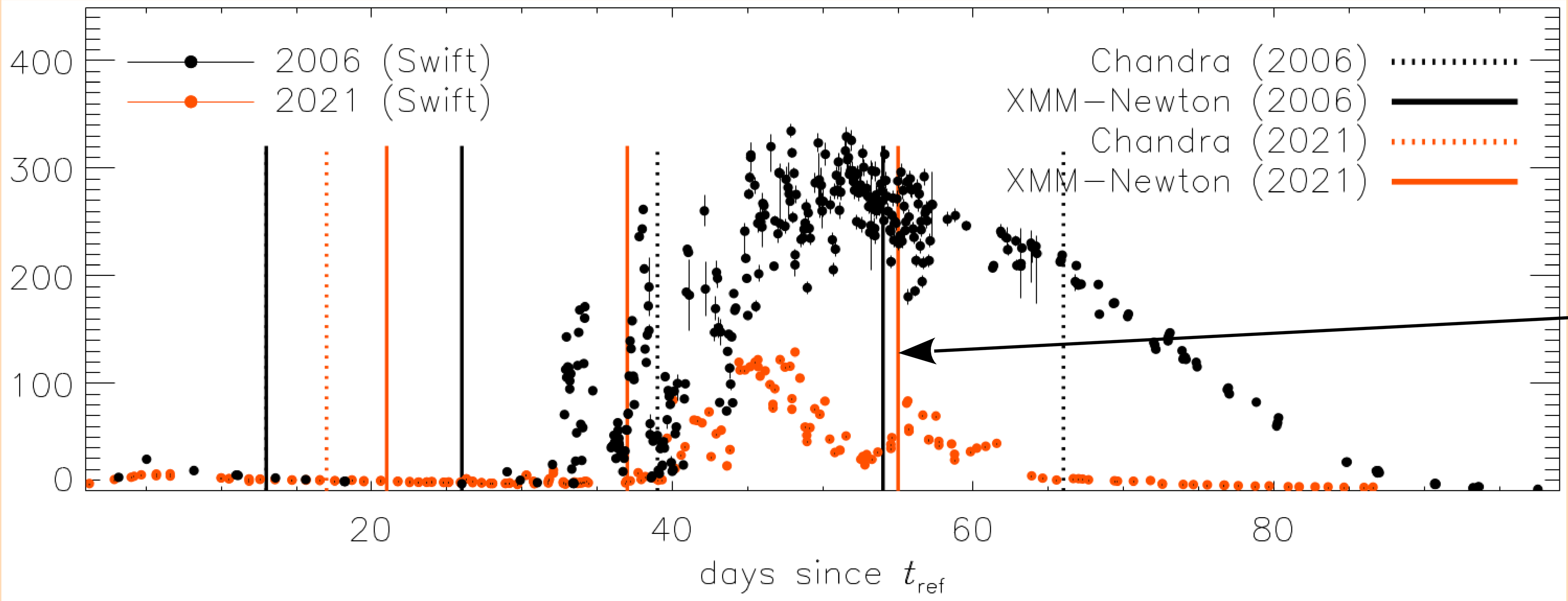
Abstract

RS Oph is a recurrent nova (powered by explosive nuclear burning on the surface of a white dwarf) exploding every 10-20 years. Since the system parameters don't change, each nova outburst should behave the same. Nevertheless, Swift found much fainter Super-Soft-Source (SSS) emission in 2021 compared to 2006. I present an unconventional approach with which 2006 and 2021 high-resolution X-ray RGS spectra can unambiguously answer the question whether this was due to less emission (e.g. lower effective temperature) or more absorption. Spectral modeling to the Swift/XRT CCD spectra, assuming blackbody or atmospheric source emission, left it ambiguous.

The problem leading to the ambiguity is the high degree of complexity of the source emission. Bypassing the challenge of finding a spectral emission model by simply multiplying a 2006 RGS spectrum by an absorption model yields a scaled spectrum impressively agreeing with the 2021 RGS spectrum.

This allows the important conclusion that the central nuclear burning engine was identical during both outbursts and that there exists no unknown process that could influence the nuclear burning rate under the same conditions. Further, the absorbing material above the white dwarf must be highly inhomogeneous leading to different absorption behaviour at different times.

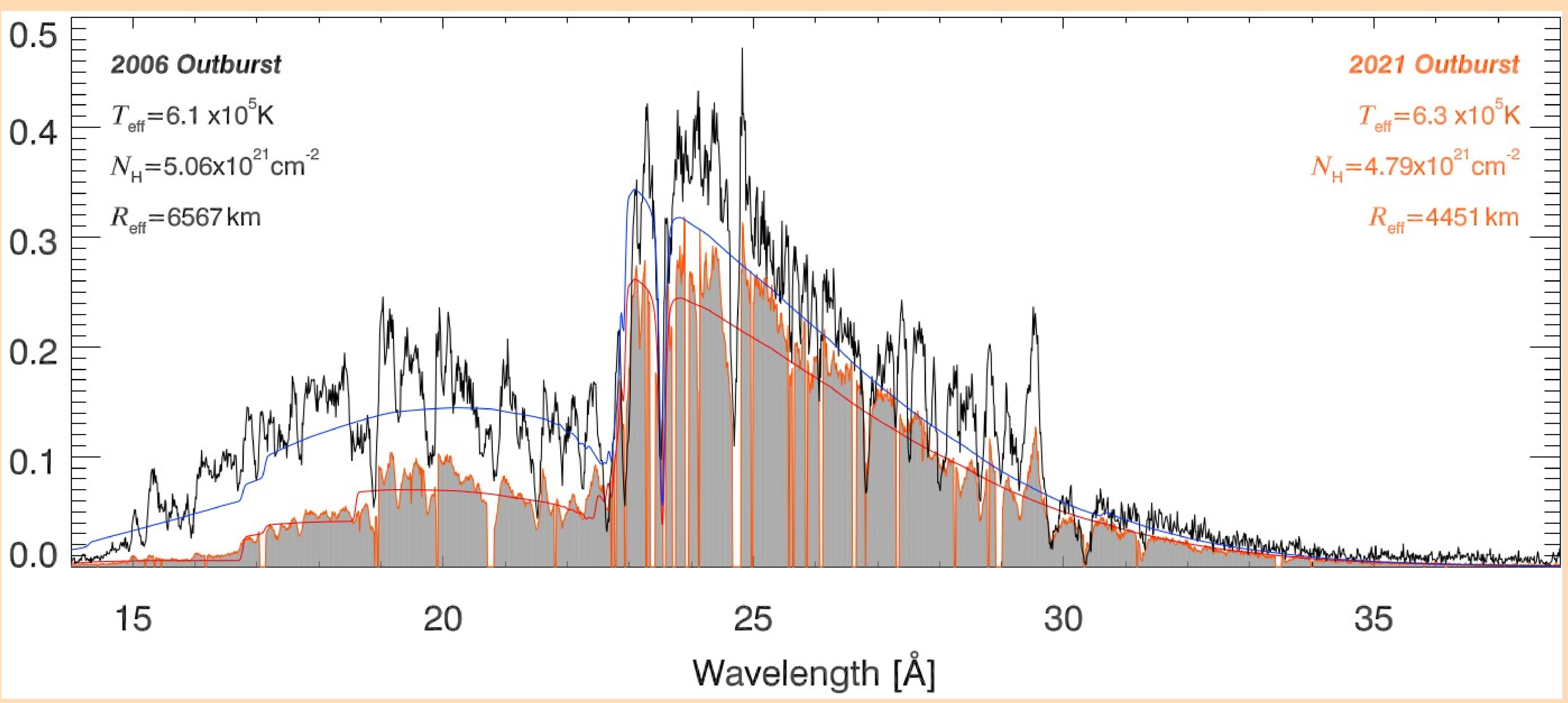


Our 2006 and 2021 Swift monitoring campaigns of RS Oph reveal much fainter soft X-ray emission in 2021 (orange) compared to 2006 (black).

This work concentrates on two XMM-Newton observations around day 55 after t_{ref}.

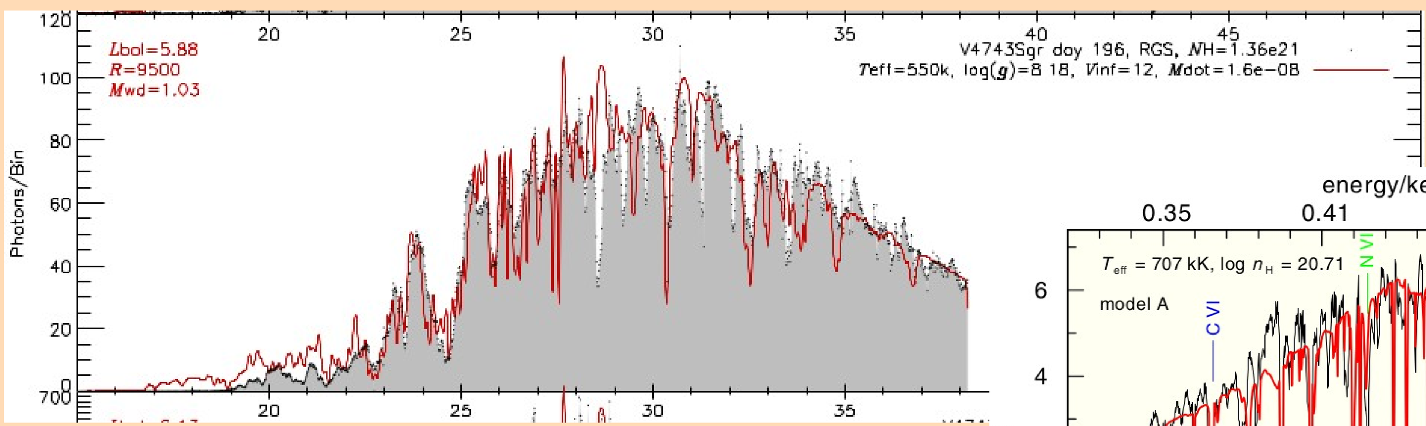
Question:
Was it fainter in 2021 because of less emission or more absorption?

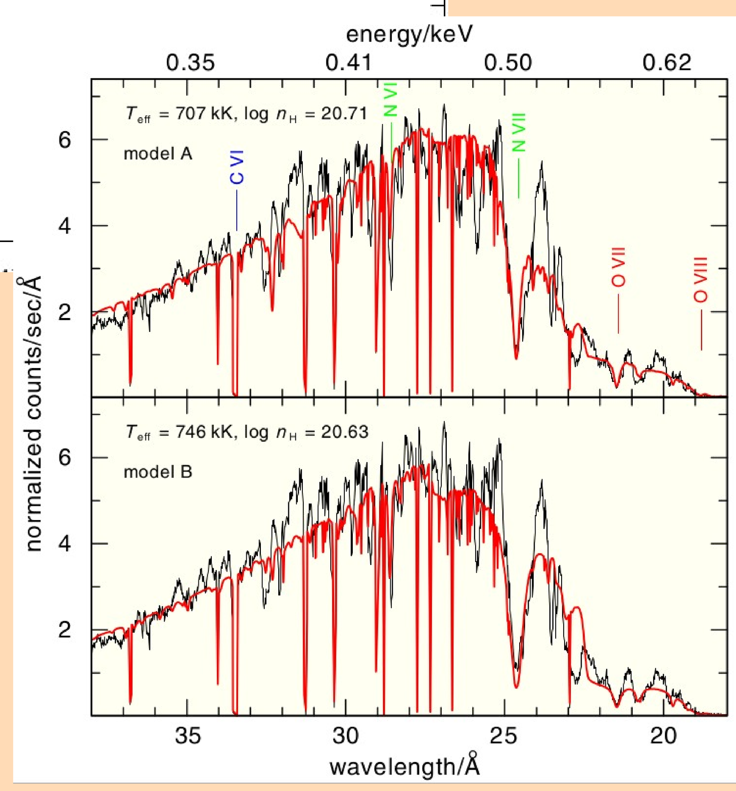
Implications:
- Less emission: Lower nuclear burning rate?
- More absorption: Complex, inhomogeneous ejecta?



Emission+Absorption models to the RGS spectra yield ambiguous results:
- T_{eff} a bit *higher* in 2021
- N_H a bit *lower* in 2021
- Emitting radius (scaling with intrinsic brightness) *lower* in 2021

No good fits => No parameter uncertainties
=> **Problem: Source model is not accurate!**





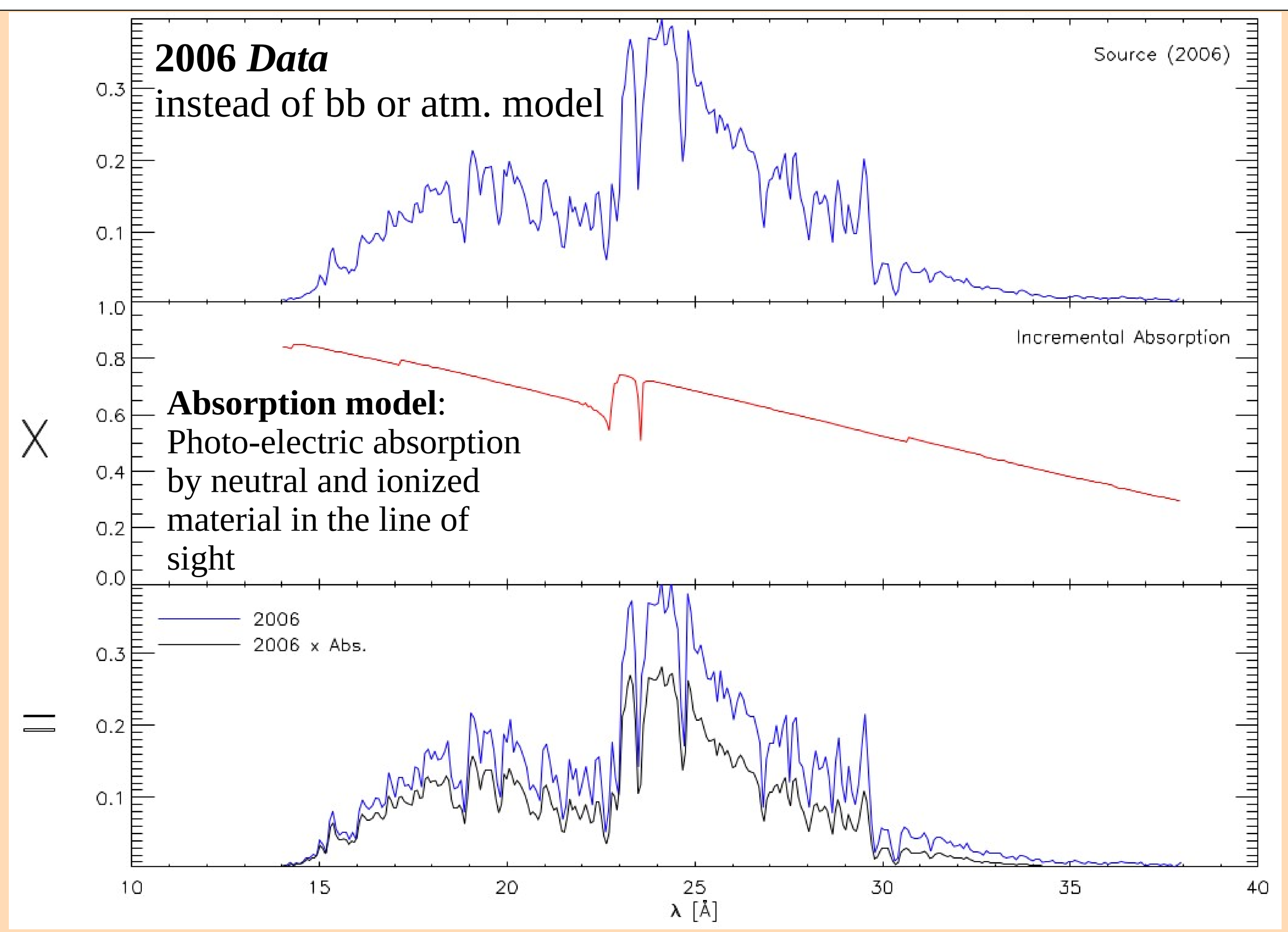
Atmosphere models make better assumptions but are still poorly understood source models

=> The obstacle is the complexity of the source *emission*

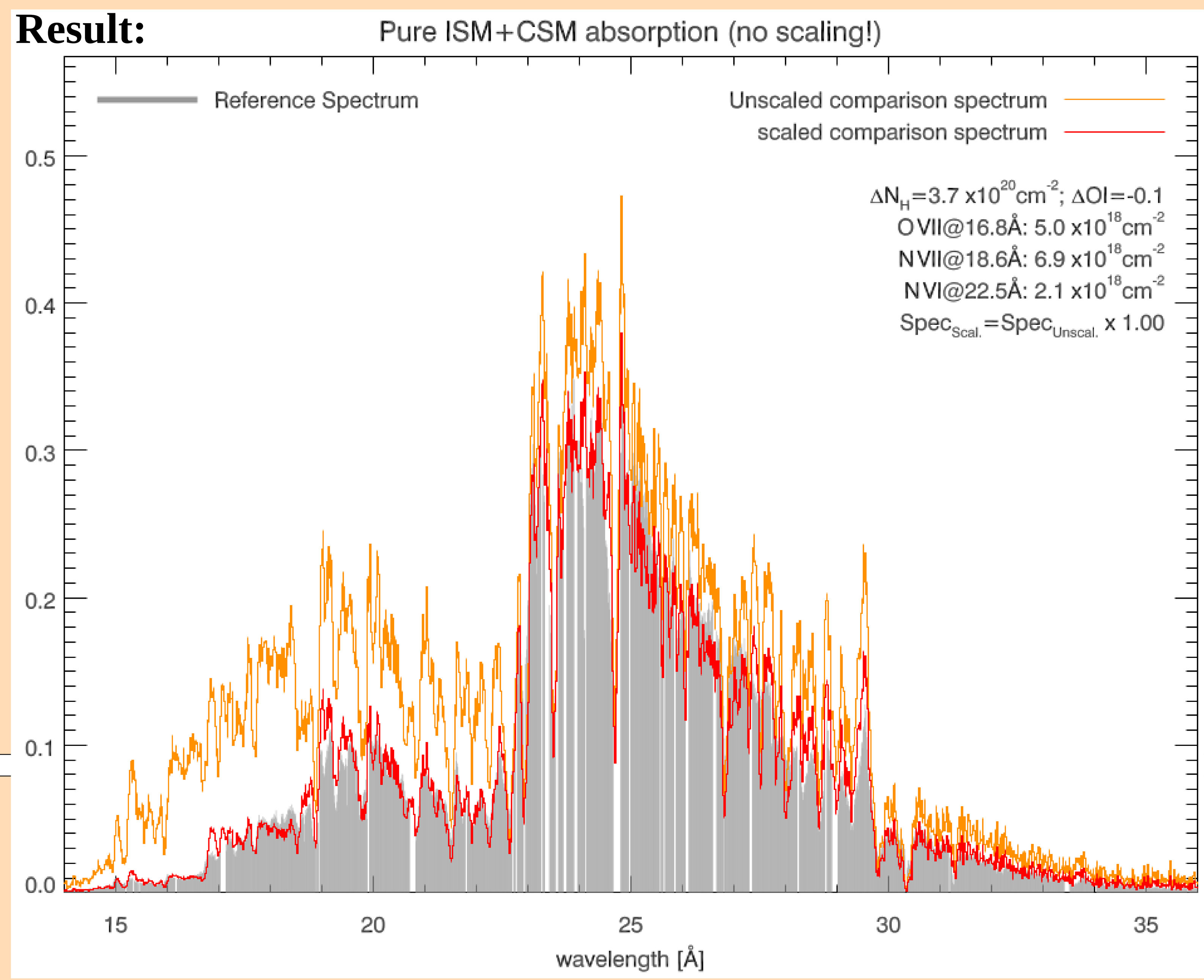
Absorption is much easier to model

The idea:
Forget about a source *model*

Multiply the *data* with an absorption model:



Result:



AMAZING reproduction of the 2021 spectrum (grey shade) by simply multiplying the 2006 spectrum (orange) with a relatively simple absorption model without any scaling! => **Thinking *out of the box*** (pun intended) **paid off!**

Conclusions:
- The unconventional approach works!
- Fainter soft emission in 2021 was *exclusively* due to more absorption
  => Absorption is time-dependent => absorbing material inhomogeneous
- Central engine produced same amount of energy in both outbursts
  => No complicated mechanism needed to understand different energy production efficiency