

Absorption Line Spectroscopy in Practice

AtomDB Spectroscopy Workshop and School
August 3-5, 2020

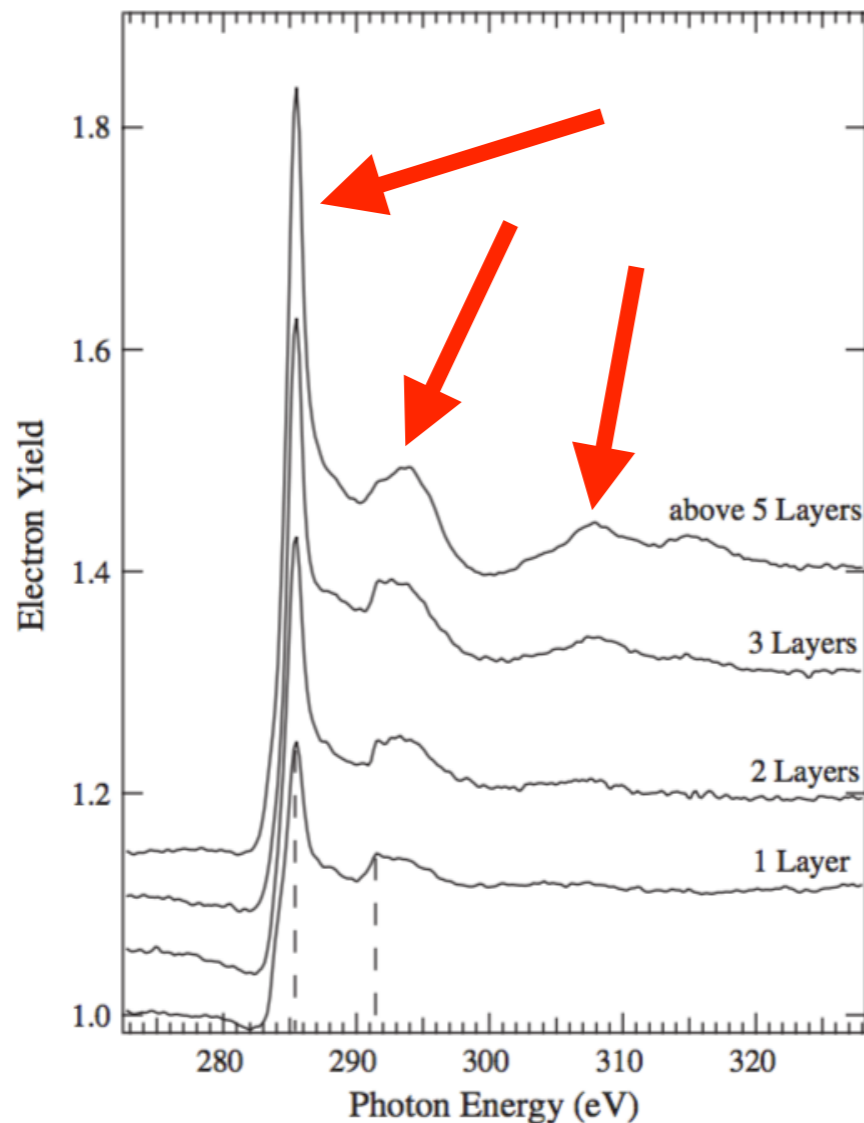
Frits Paerels

with Richard Nederlander, Joheen Chakraborty, Margo Collins,
John Staunton, Kyle Neary, Kate Steiner, Tanisha Jhaveri,
Hunter Holland, Kate Miller, Susannah Abrams, Tze Goh,
Bhairavi Chandersekhar,
Aswath Suryanarayanan, Johon Milla, and Navin Sridhar

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I. Funny Line Shape: Neutral Carbon in the ISM

many open ISM questions-
for instance: what form is most of the interstellar carbon?
graphite? *graphene*? polycyclic molecules?

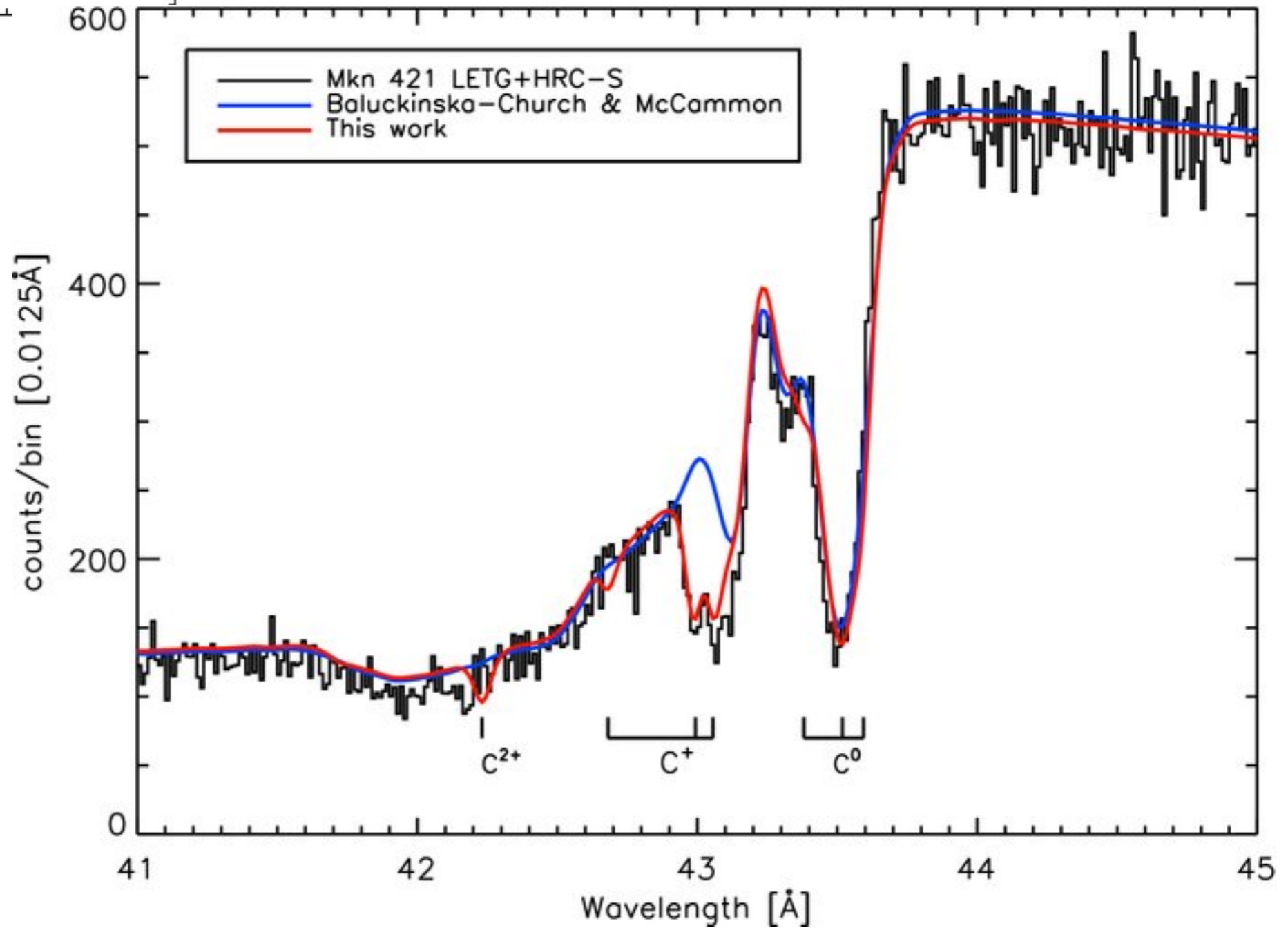
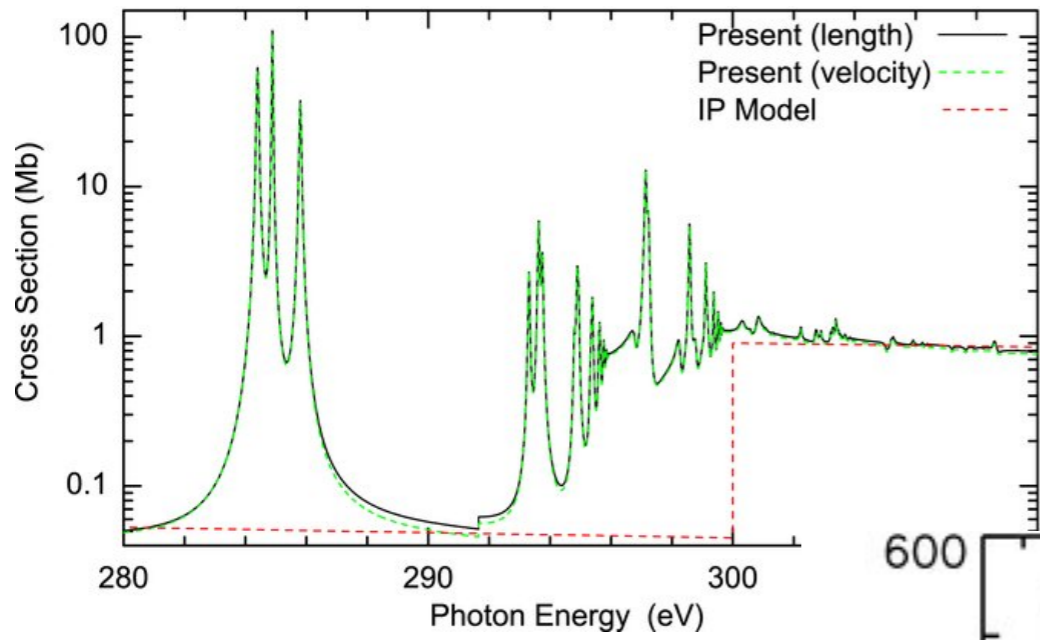


X-ray spectroscopy can tell us:

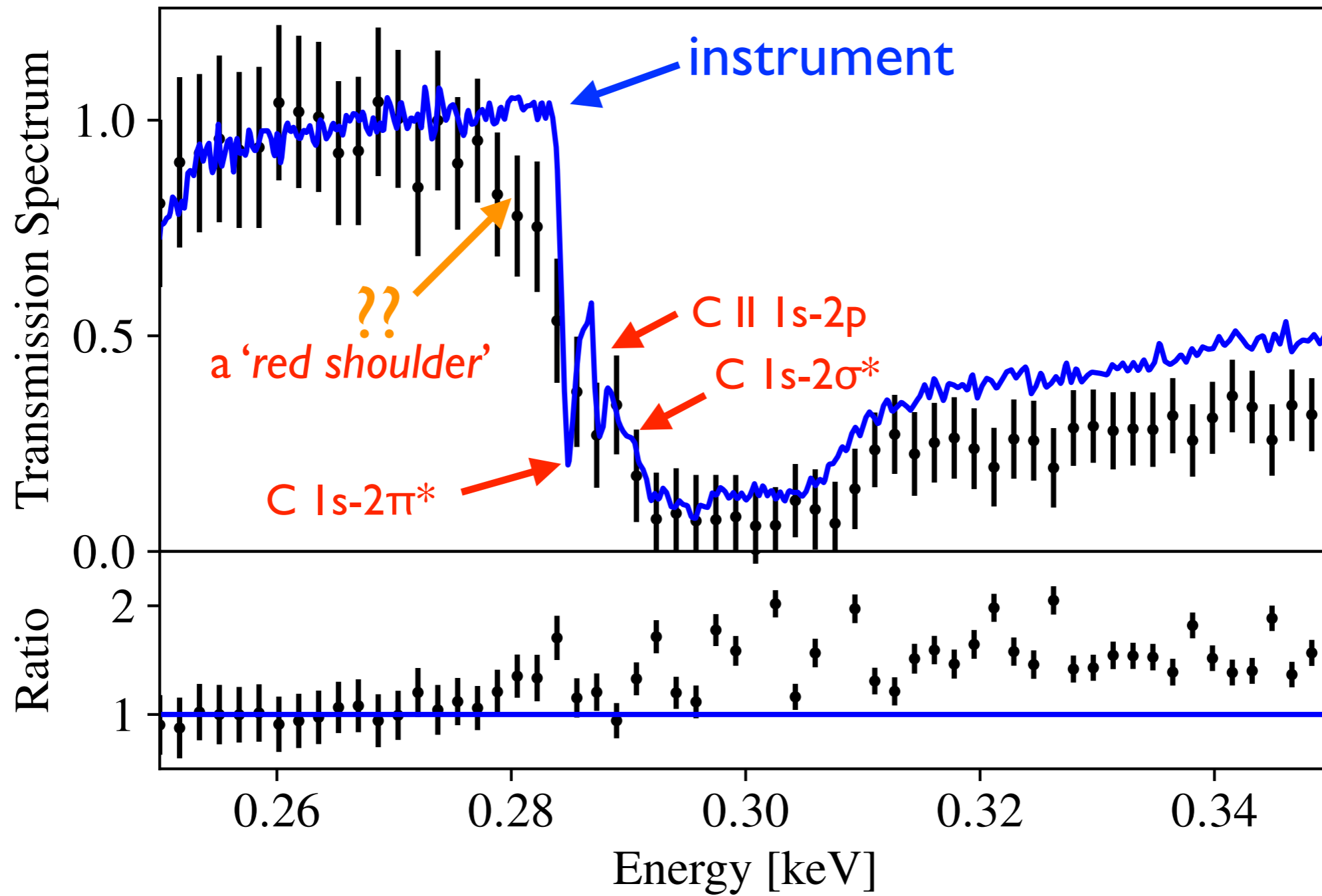
*absorption spectroscopy
of the interstellar medium around the
carbon-K edge (280 eV), using the
LETGS on the Chandra X-ray Observatory
(with John Staunton)*

FIG. 2. C *K*-edge photoabsorption spectra of (from the bottom): graphene, bilayer graphene, and FLG samples. The dashed lines show the C *1s* π^* and C *1s* σ^* transitions.

LETGS UV/IS: plastic....



Mkn 421 / LETGS
Hasoğlu *et al.* 2010



IES 1553+113 LETGS/ 500 ksec

real and imaginary parts of the polarizability of the harmonic oscillator:
imaginary part: *absorption*, real part: *scattering*

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Classical Electrodynamics

Sect. 7.5

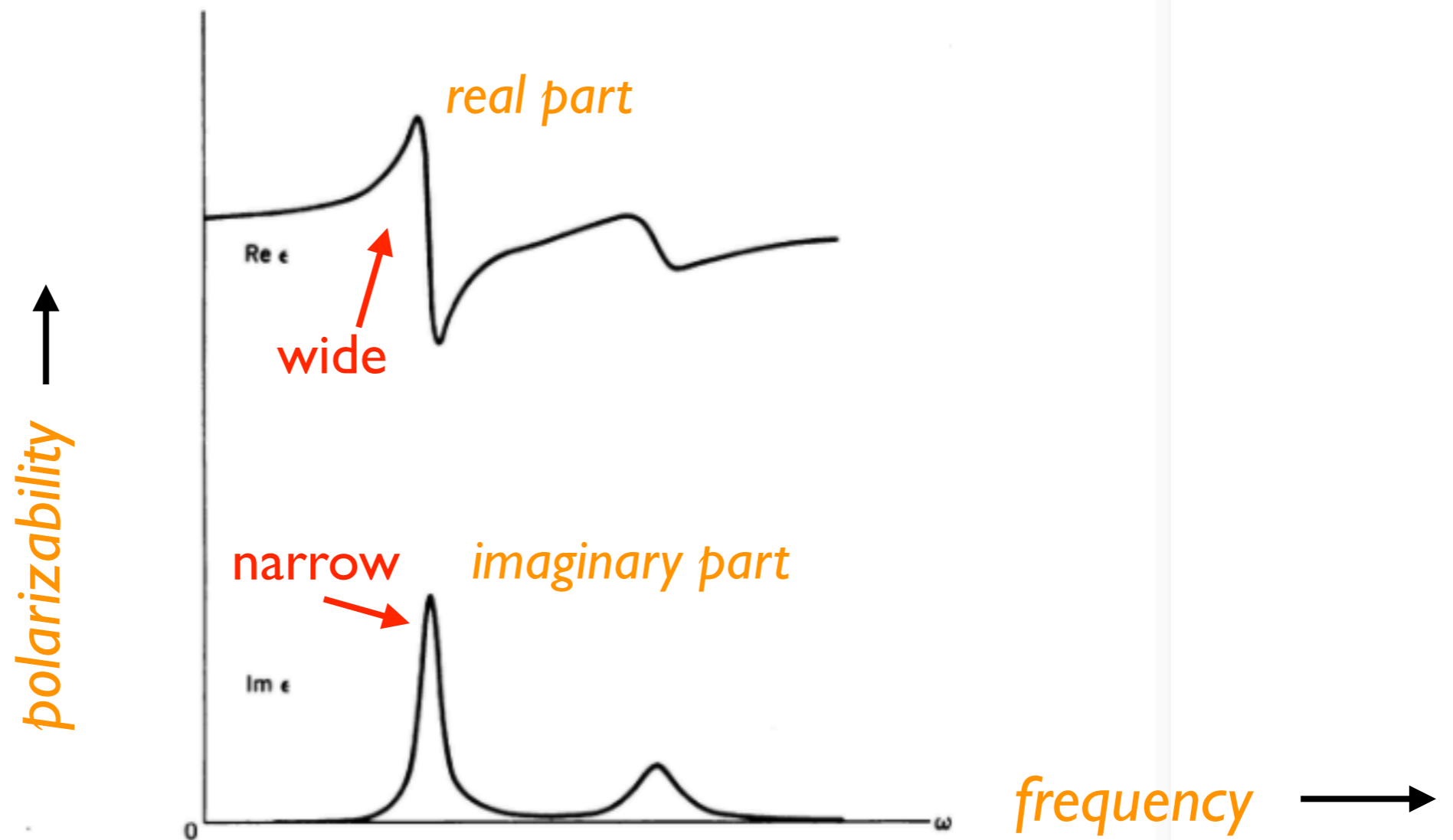


Fig. 7.8 Real and imaginary parts of the dielectric constant $\epsilon(\omega)$ in the neighborhood of two resonances. The region of anomalous dispersion is also the frequency interval where absorption occurs.

J. D. Jackson: *Classical Electrodynamics*

scattering contributes to *extinction*;

if scattering angles large enough:

radiation removed from the beam- looks like absorption

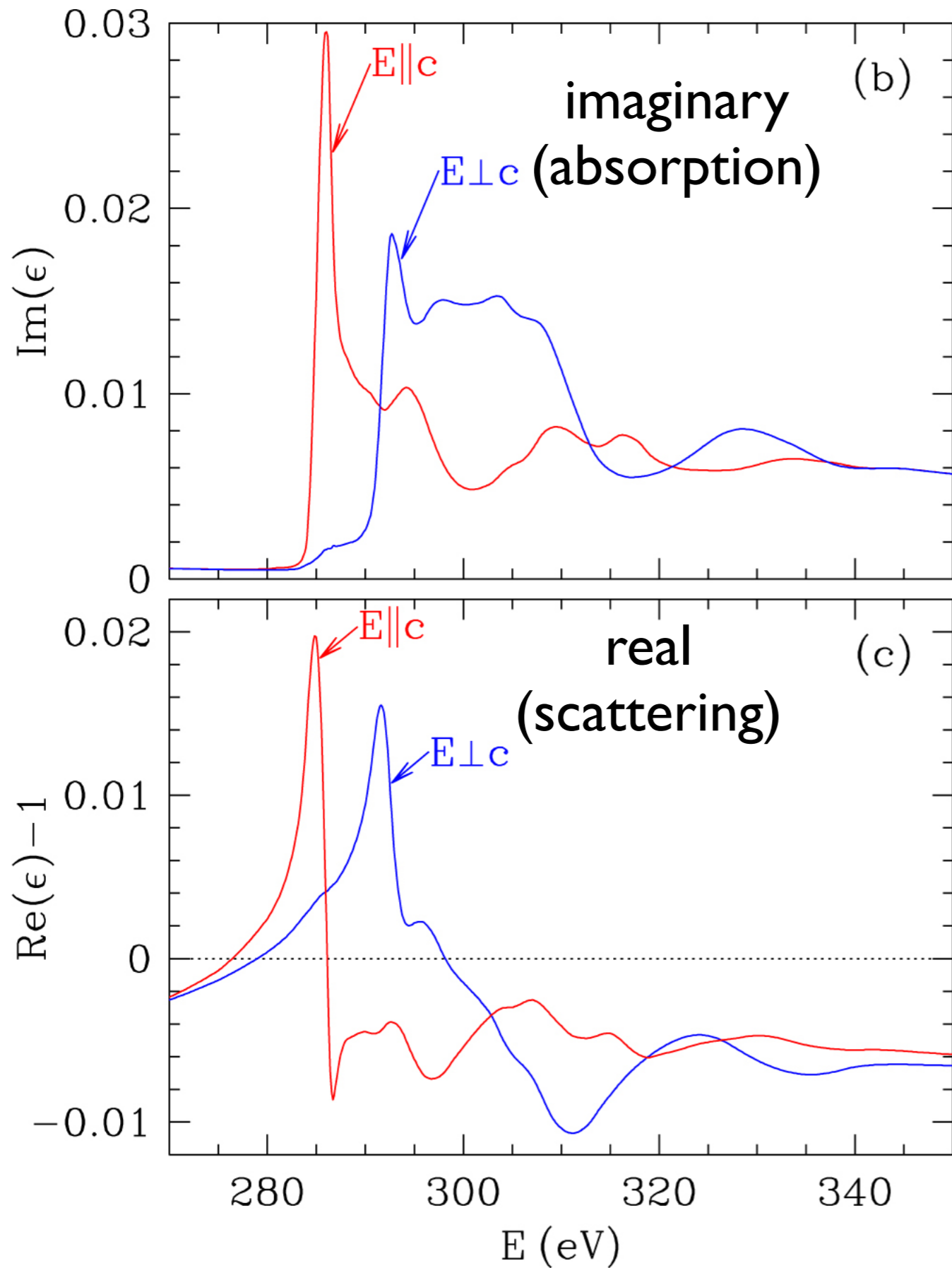
scattering angle:

sphere of radius a , wavelength λ :

$$\theta \sim \lambda/a = 2.5 (\lambda/44 \text{ \AA}) (a/0.1 \mu\text{m})^{-1} \text{ degrees!!}$$

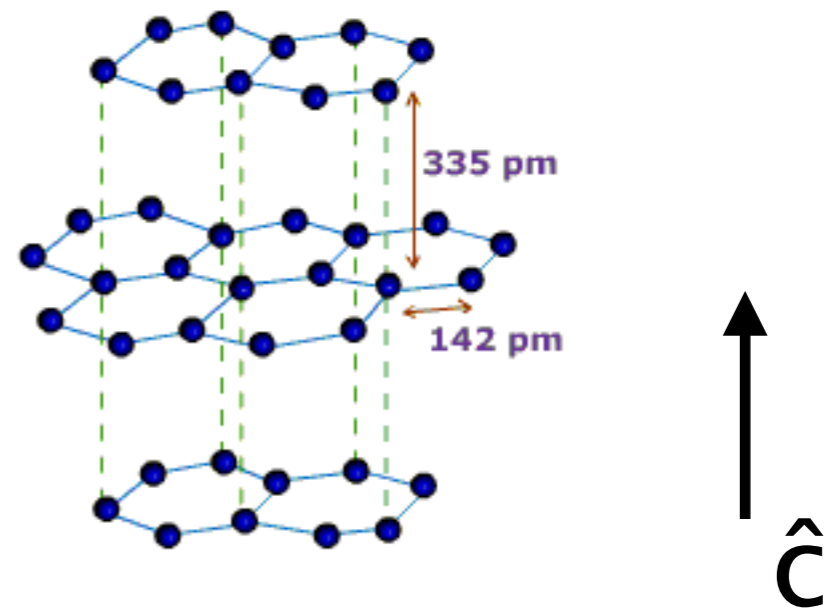
>> *Chandra* angular resolution,

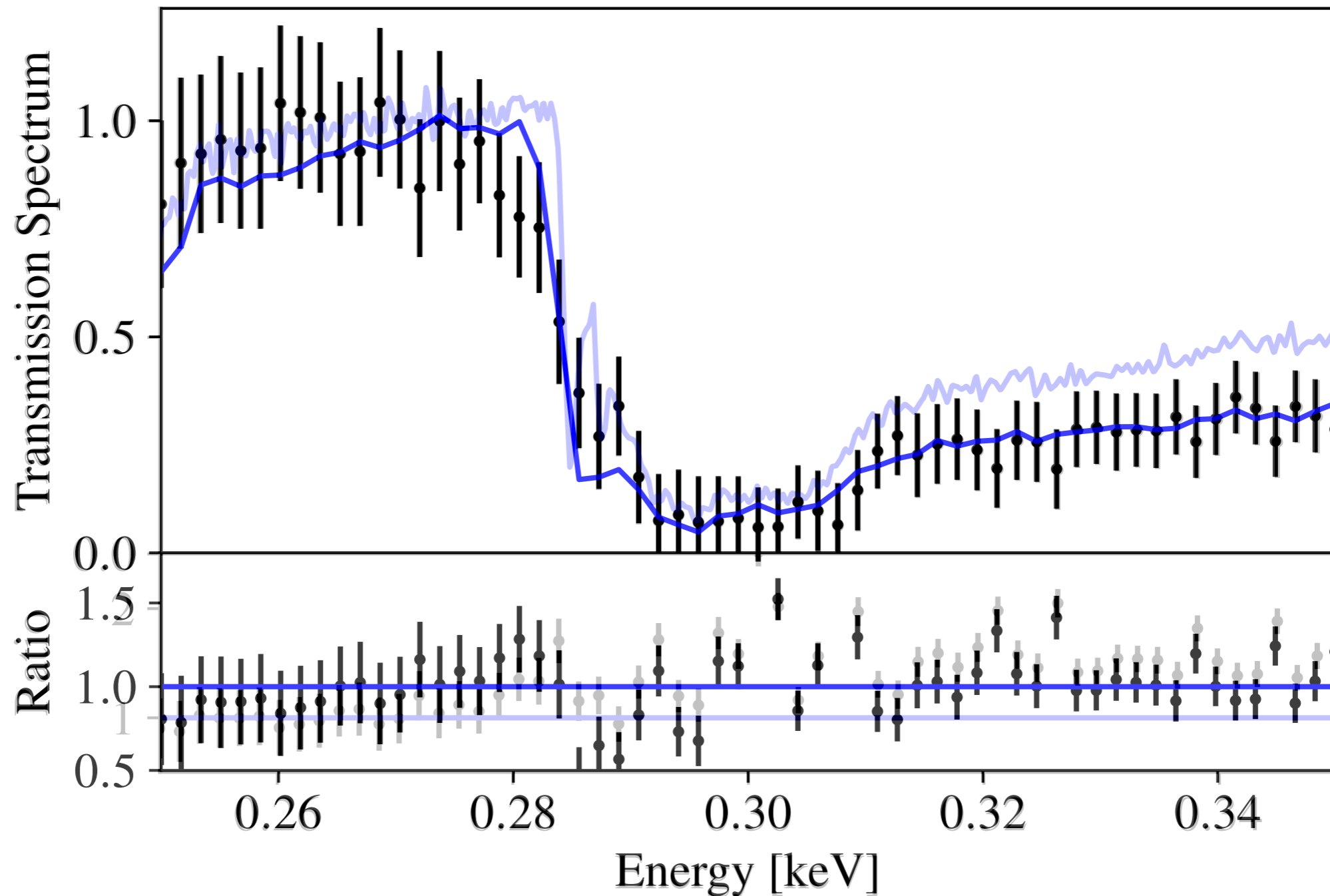
so the scattered light 'disappears from the image'



the real polarizability
of graphite
(Draine 2016)

also: the scattering is
orientation and
polarization dependent

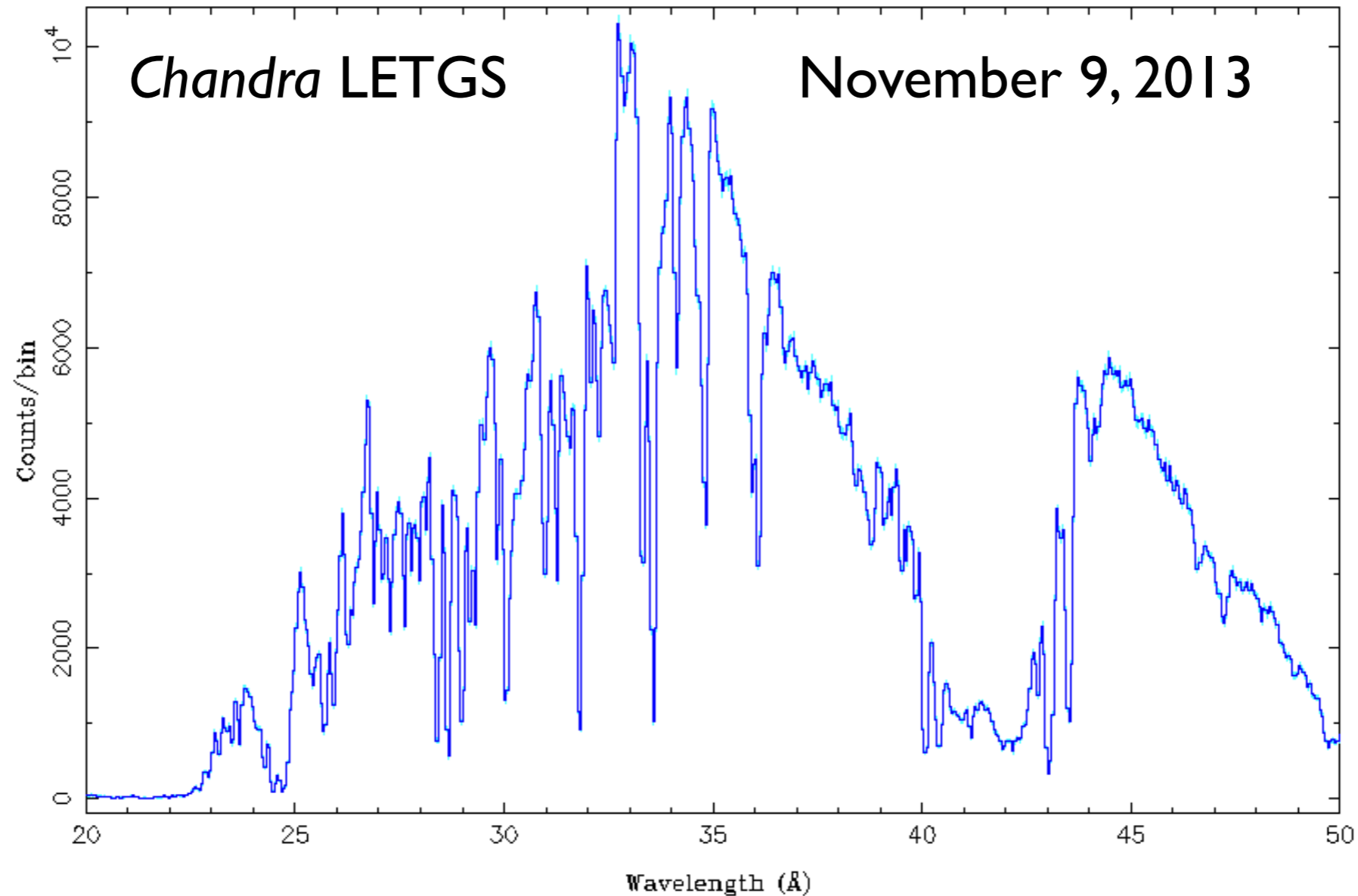




fit scattering by 0.1-0.2 μm graphite spheres,
random orientation, no polarization; C mass column fixed
? possibly indicative of polarization and/or alignment?

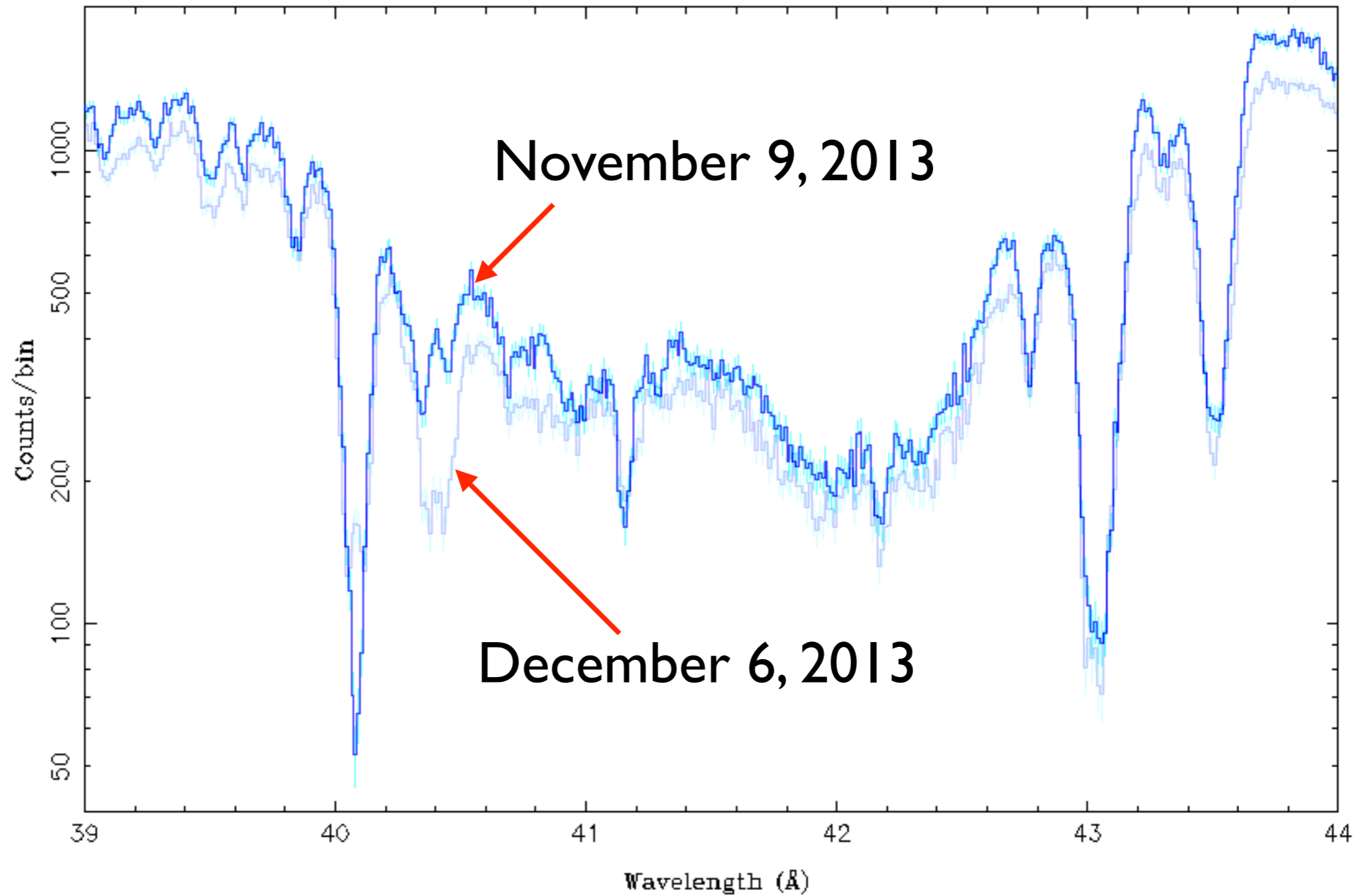
2. Funny Curve of Growth: Absorption by a Nova Shell

Nova Delphini 2013 went off on August 14, 2013

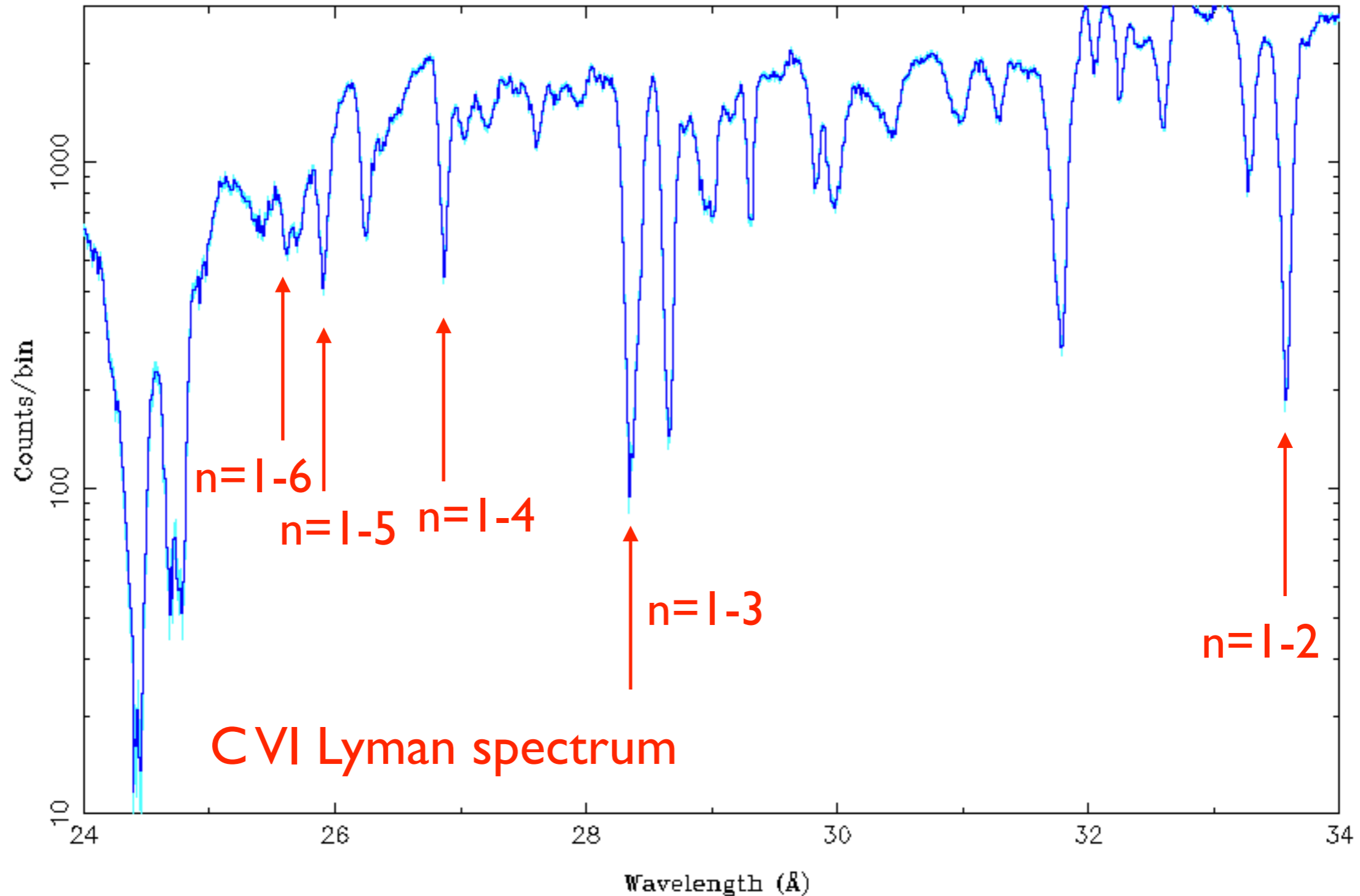


extraordinary spectrum of the WD photosphere; $T_{\text{eff}} \sim 700,000 \text{ K}$
(with *Johon Milla*)

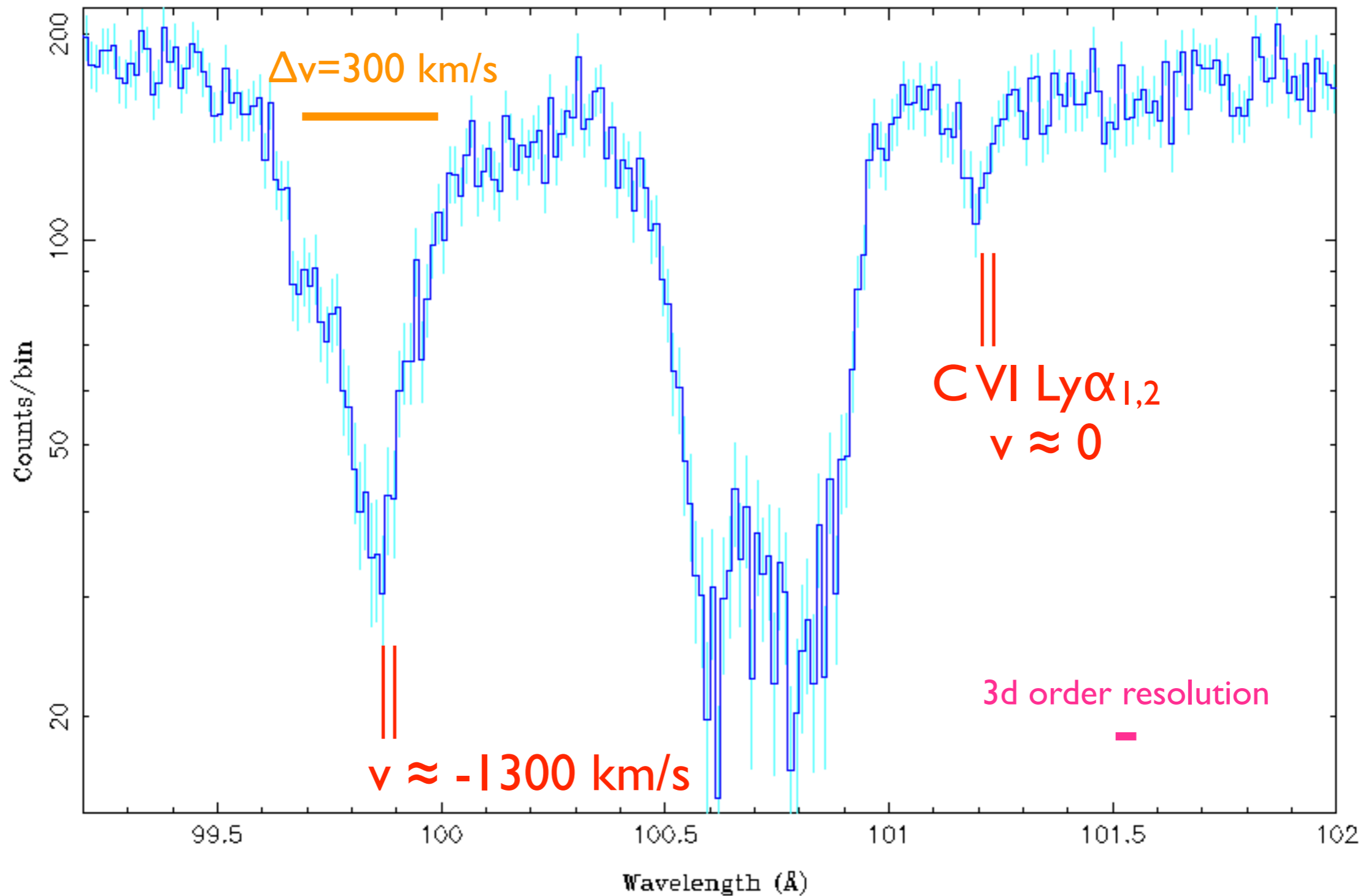
(and in fact the spectrum is variable)



pulling the spectrum apart:
evidence for *circumstellar* absorption
(huge Doppler blueshift)



Nova Del 2013: third order LETG



rest frame: C VI Ly $\alpha_{1,2}$: 33.741, 33.735 Å

CVI

$n=1-2$

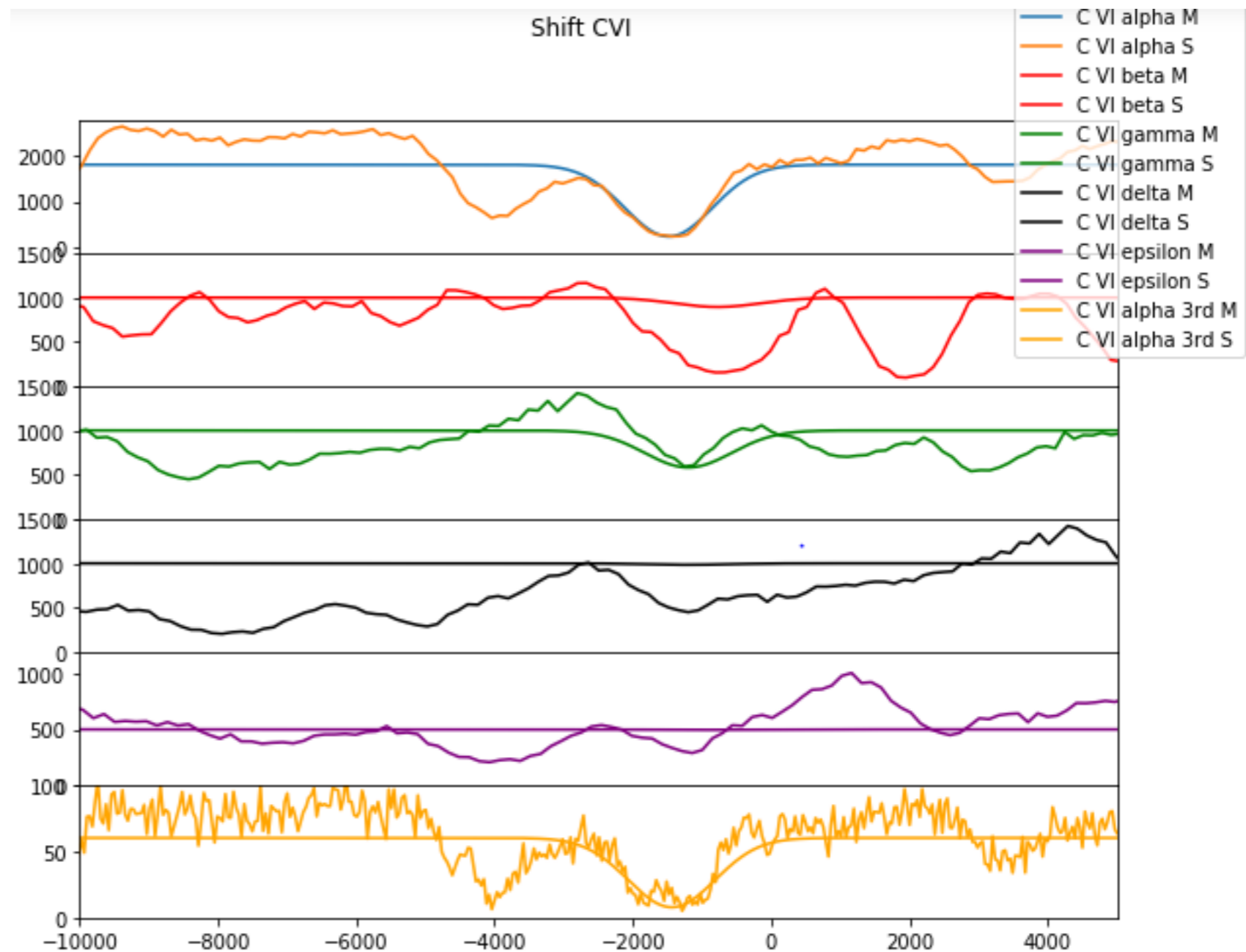
$n=1-3$

$n=1-4$

$n=1-5$

$n=1-6$

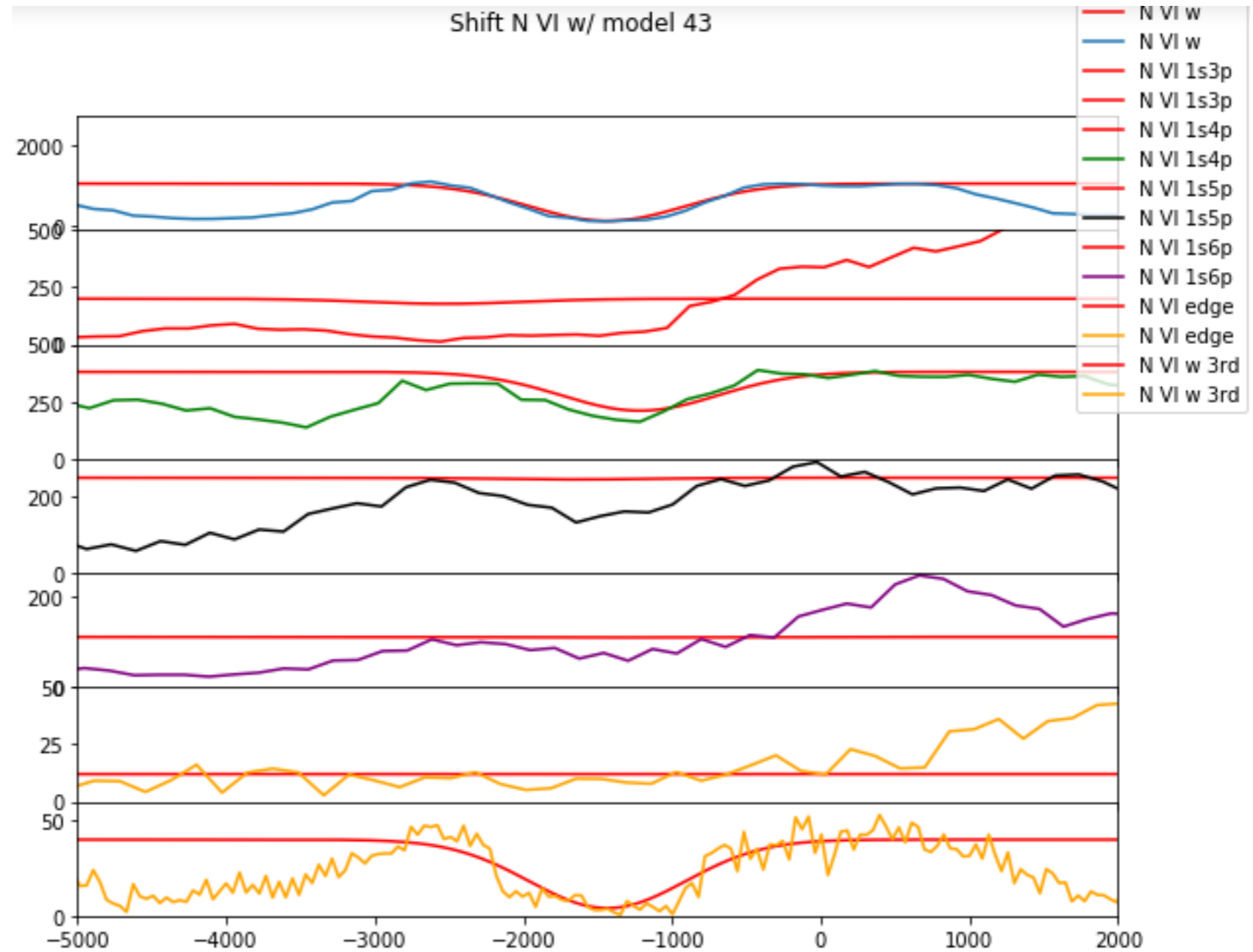
$n=1-3, m=3$



$v \approx -1300 \text{ km/s}$

N VI

$n=1-2$
 $n=1-3$
 $n=1-4$
 $n=1-5$
 $n=1-6$
 $n=1-3, m=3$



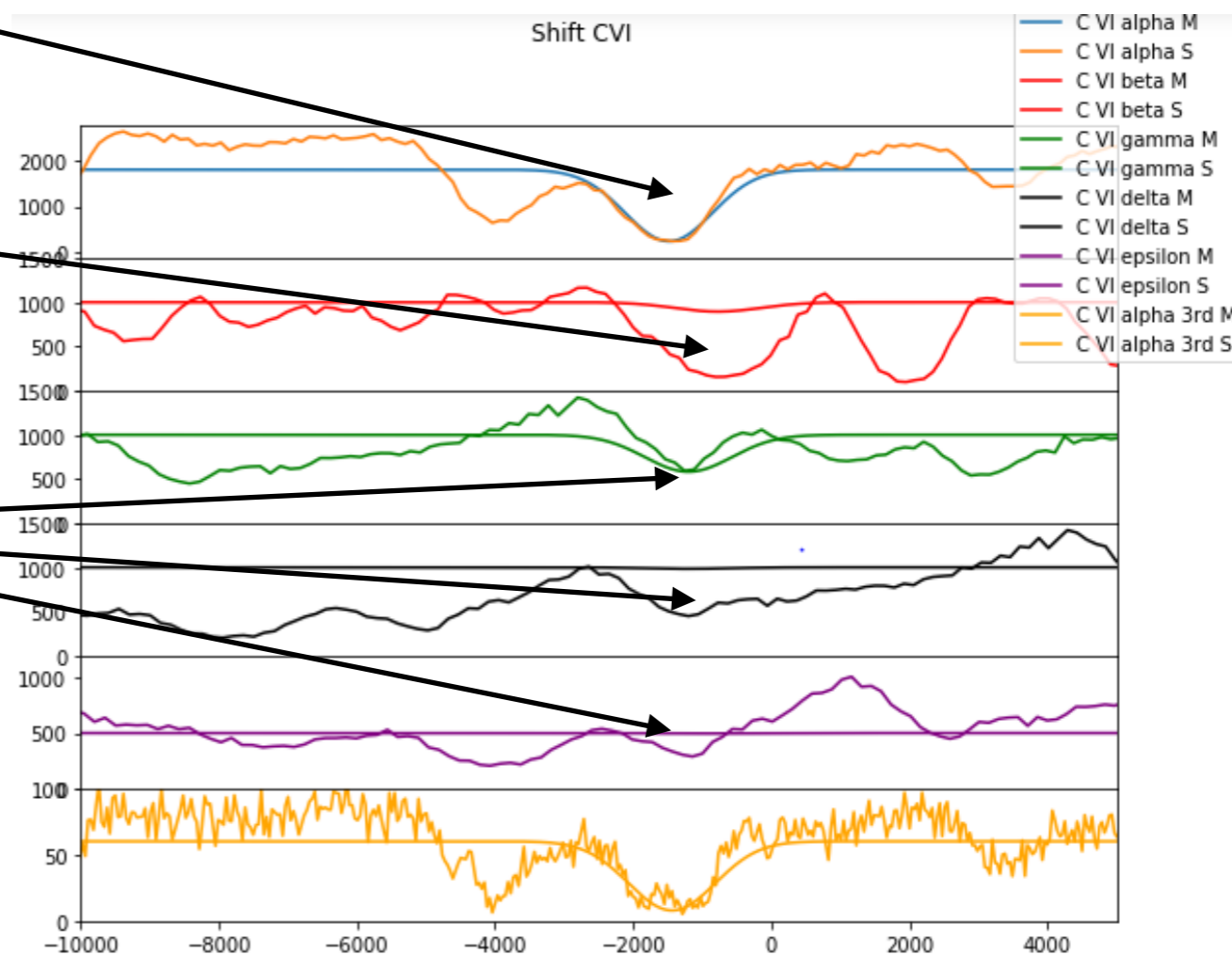
same velocity offset in N VI (and CV)

Now we want to measure the ion column densities
(get mass, kinetic energy of the shell)

Ly α possibly saturated

Ly β fatally blended?

continuum level at Ly γ , δ , ϵ ?
EW's very large
compared to Ly α ??



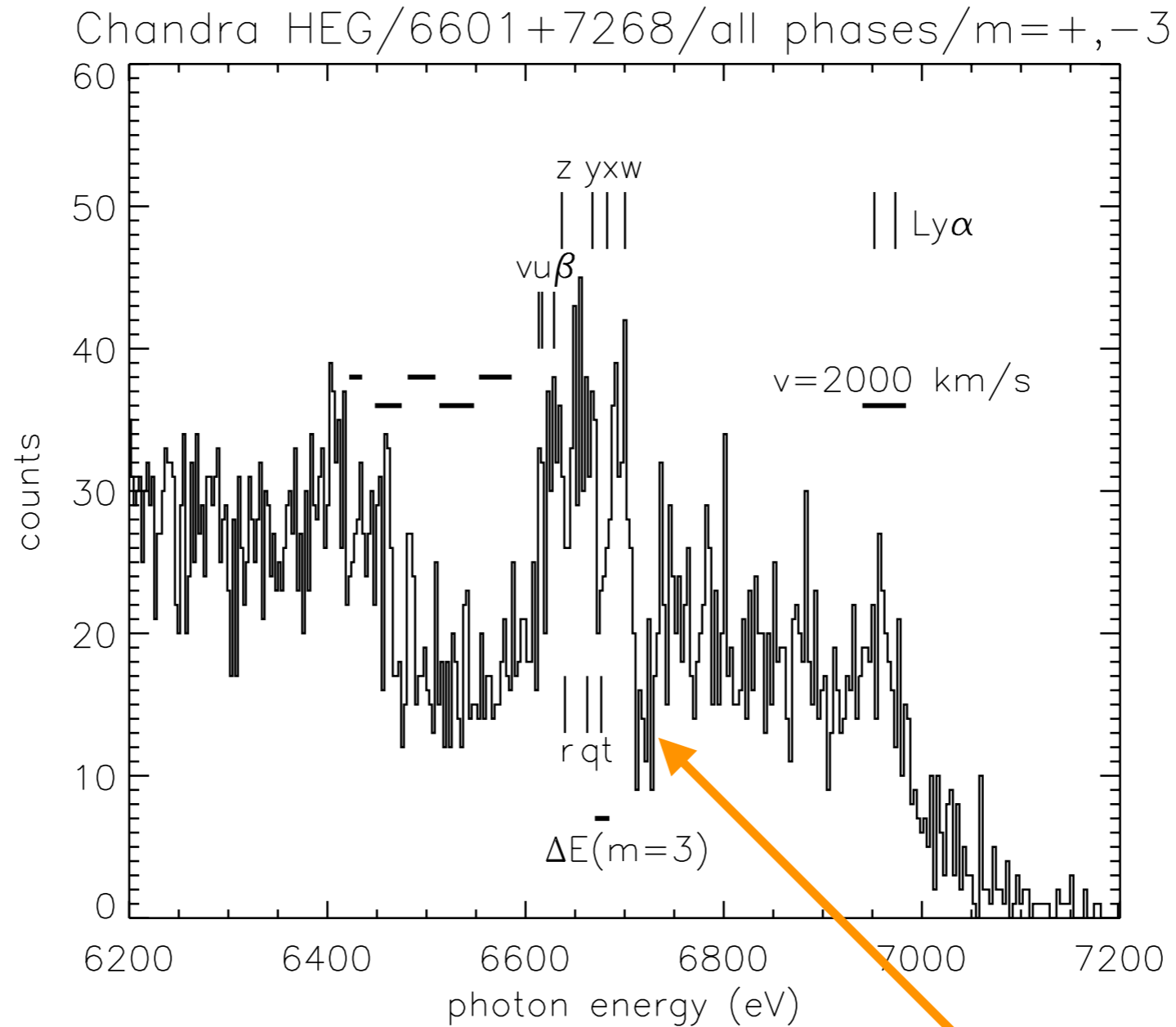
curve of growth is a mess!

Use Ly α $m=3$; ignore/discard the higher series members

*statements of general validity,
and possibly of educational value*

1. Basic physics is fun and pops up everywhere
2. Be prepared to ignore confusing evidence if you can identify a rational basis for doing so

and an encore: *Chandra* HETGS Cygnus X-3 $m=3$ (with Aswath Suryanarayanan)



a P Cyg profile on the
He-like Fe resonance line

*with my gratitude to all the students,
and best wishes for everyone.*