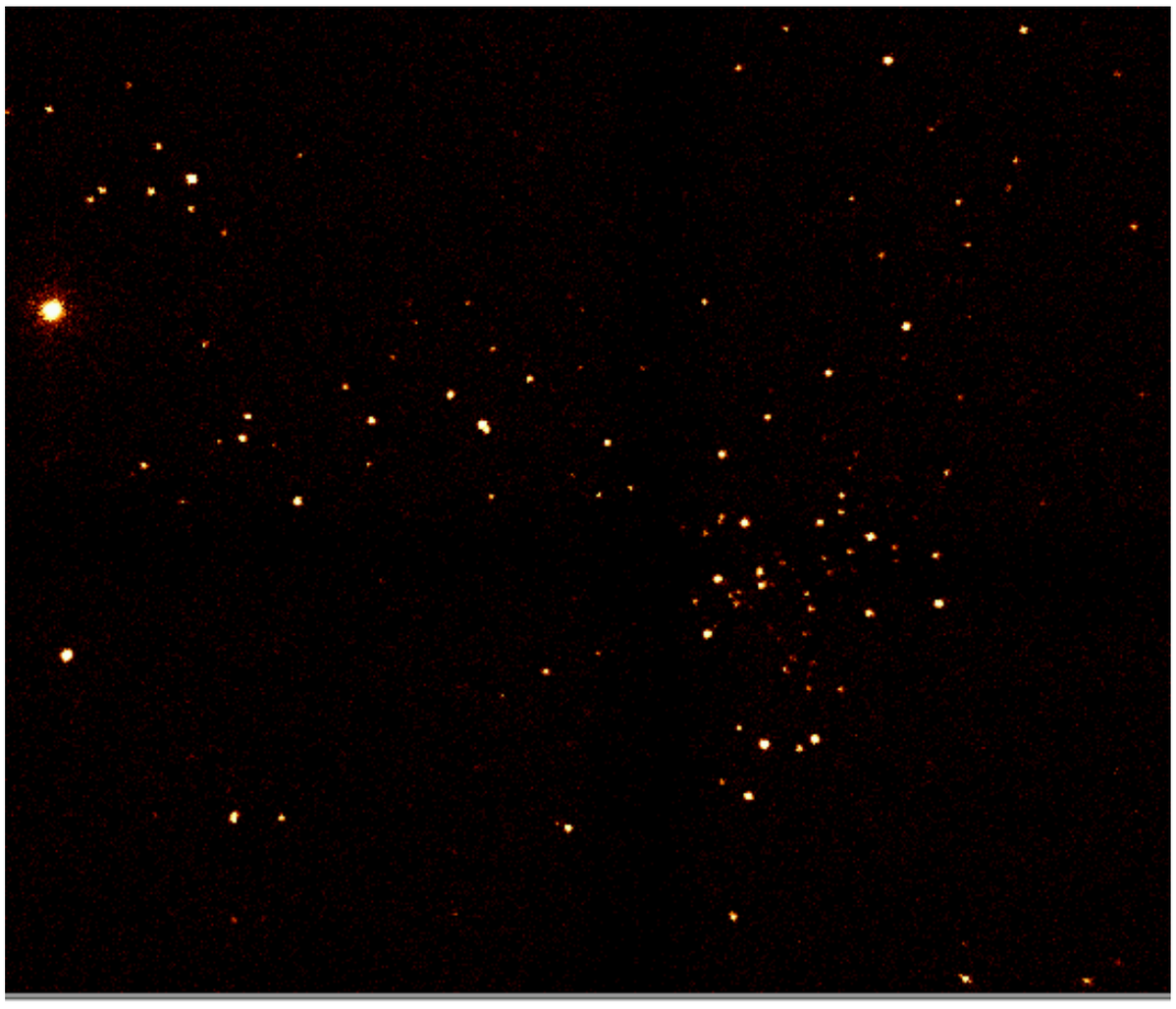
Status Report 10 July 2006

Content

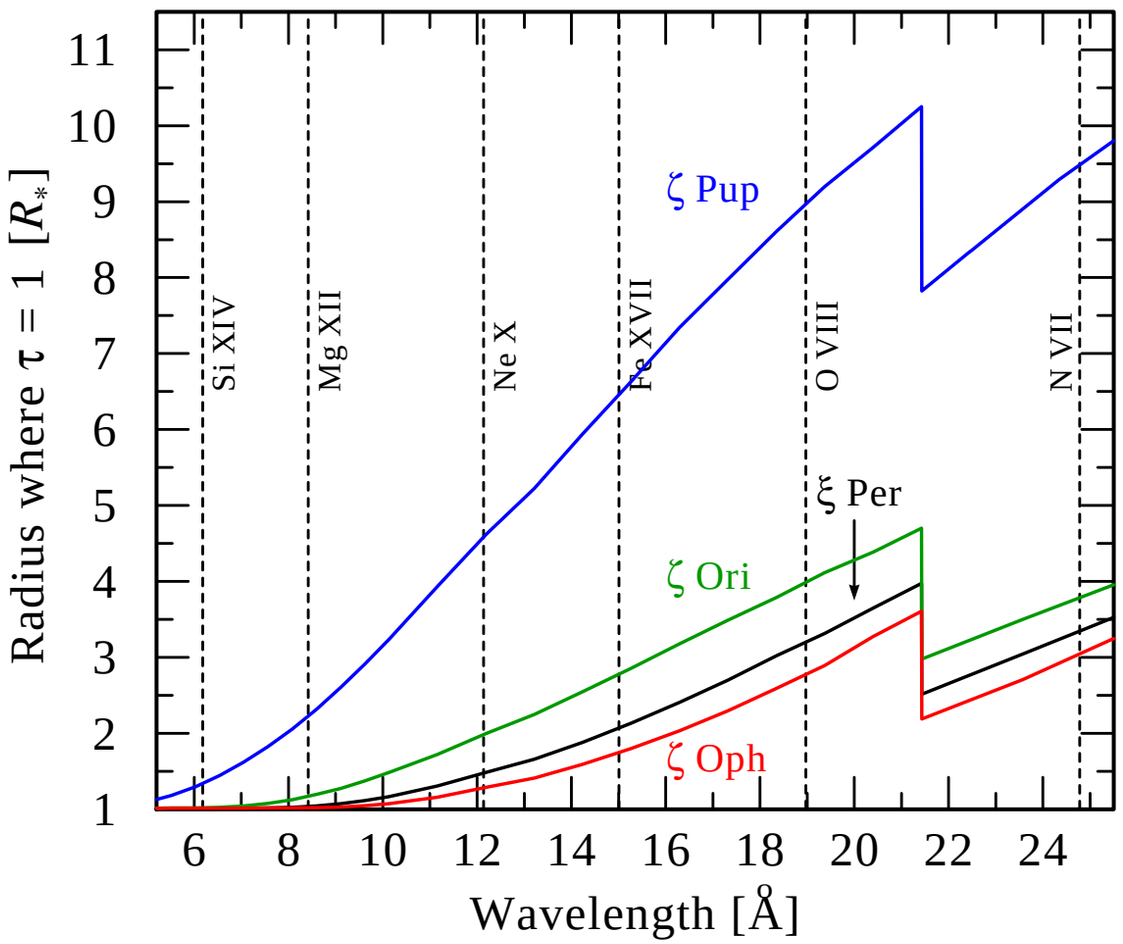


A&A Letter (in prep.) There is no correaltion between an age of massive stars and its X-ray activity. On the presence of magnetic filds in youngest O stars.

← Her 36: weak X-ray source

- X-ray Line profiles : Balls or Pancakes
- "New" spectra of ζ Pup: stochastic variability
- Line opacity with Clumps: PoWR Blobs

Chandra spectra of ζ Pup, ζ Ori, ζ Oph, and ξ Per



- Chandra spectra of four single brightest O stars are retrieved and analysed.
- X-rays emission is from hot plasma, X-rays are absorbed by the continuum of cool wind → pure absorption RT
- Cool wind opacity from PoWR model, microclumping, X-rays
- Paper was submitted on 6th February (MNRAS)!

We assumed that wind is clumped. The only "free" parameter specifing opacity is fragmentation frequency.

Clumping Terminology

- Density within each clump is higher than average by factor D.
- All processes (e.g. scuttering) which scale with density are affected.

- Optically thin Clumps $\tau_{\mathrm{clump}} \ll 1$: Photons do not "notice" these clumps
- Optically thick Clumps $\tau_{\mathrm{clump}} \gg 1$: photons are absorped in the clump

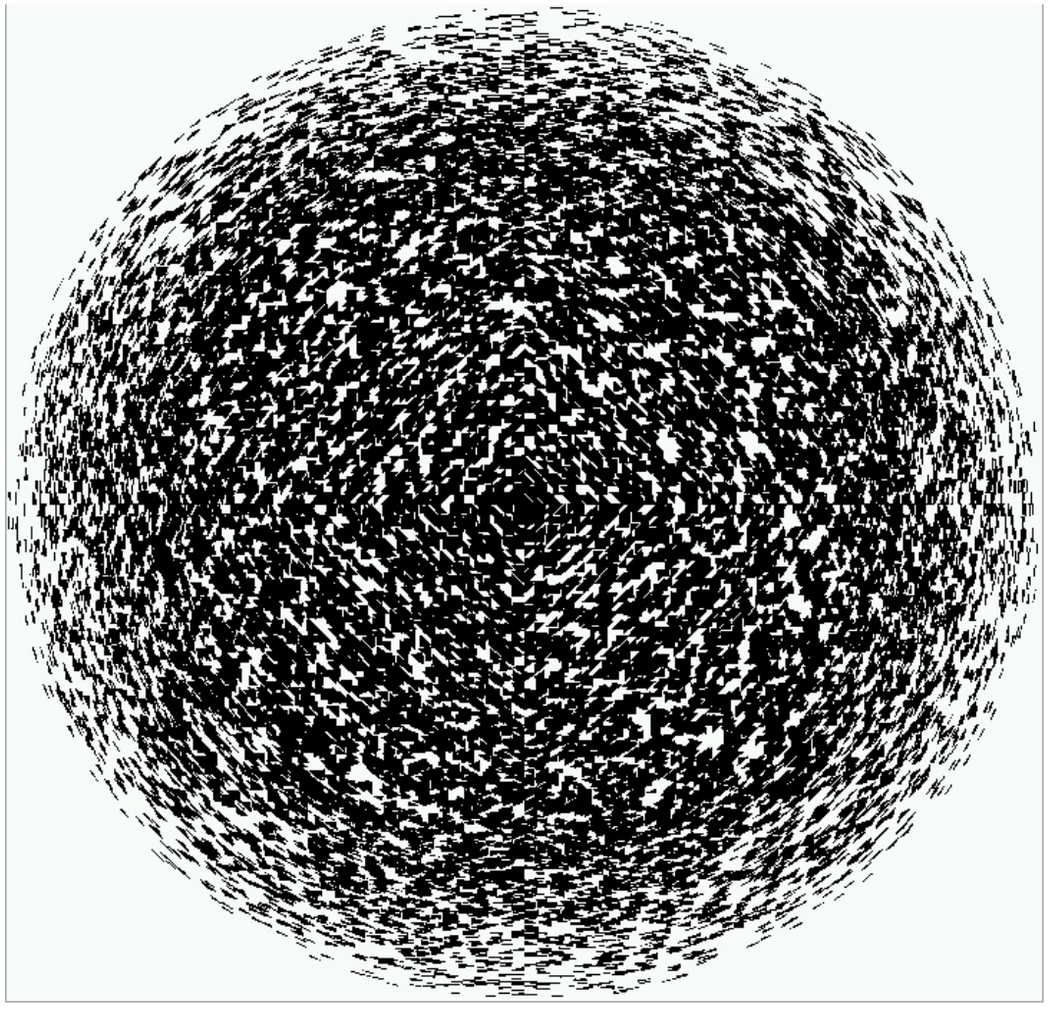
Number clumps $n(r) = \frac{n_0}{r^2 v(r)}$ [cm^{-3}]

Fragmentation frequency $[n_0] = \mathrm{s}^{-1}$

Terminal porosity length $h_\infty = \frac{v_\infty}{n_0}$ [cm]

Effective opacity

Sky projection of a model stellar wind



The effective opacity is the product of

- number density of clumps $n(r)$
- cross section of the clumps σ
- probability that an X-ray photon which hits a shell is absorbed

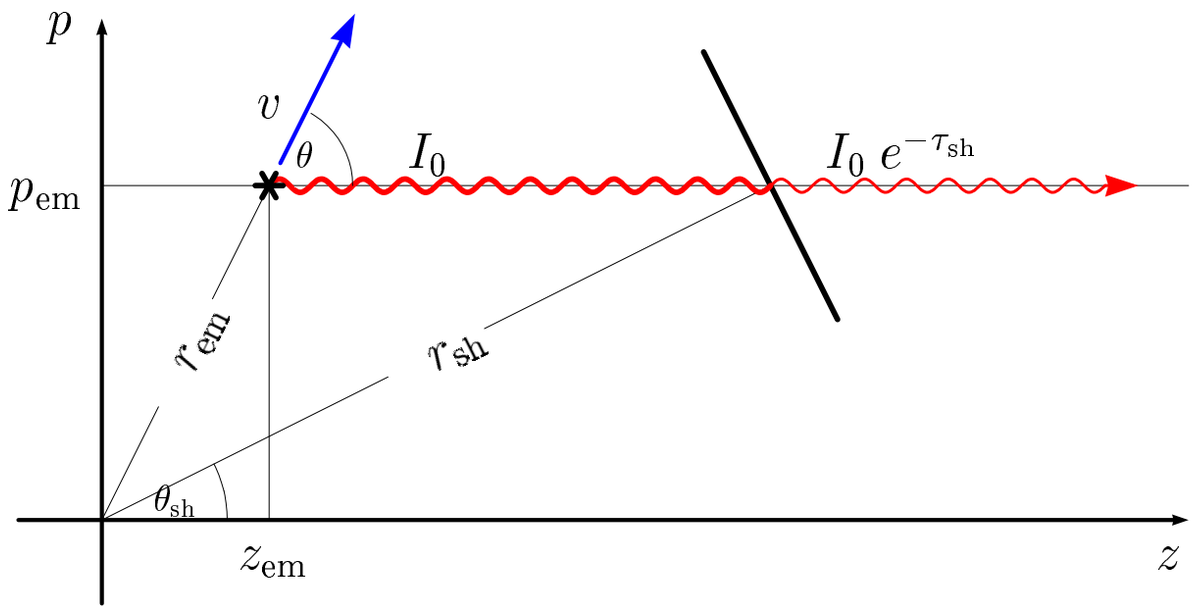
Effective optical depth between an emitting point and observer:

$$\tau = \int_z^\infty n(r)\,\sigma\,(1 - \mathrm{e}^{-\tau_{\mathrm{clump}}})\,dz$$

Optically thin clump limit → smooth wind

The effective optical depth in the clumped wind is determined by the geometrical distribution of clumps

Two limits of clump shape: Balls and Pancakes



- Spherical clumps $\Rightarrow$ cross-section does not depend on angle: $\sigma \sim r^2$
- Oblique clumps $\Rightarrow$ $\sigma \sim |\mu| r^2$

Balls

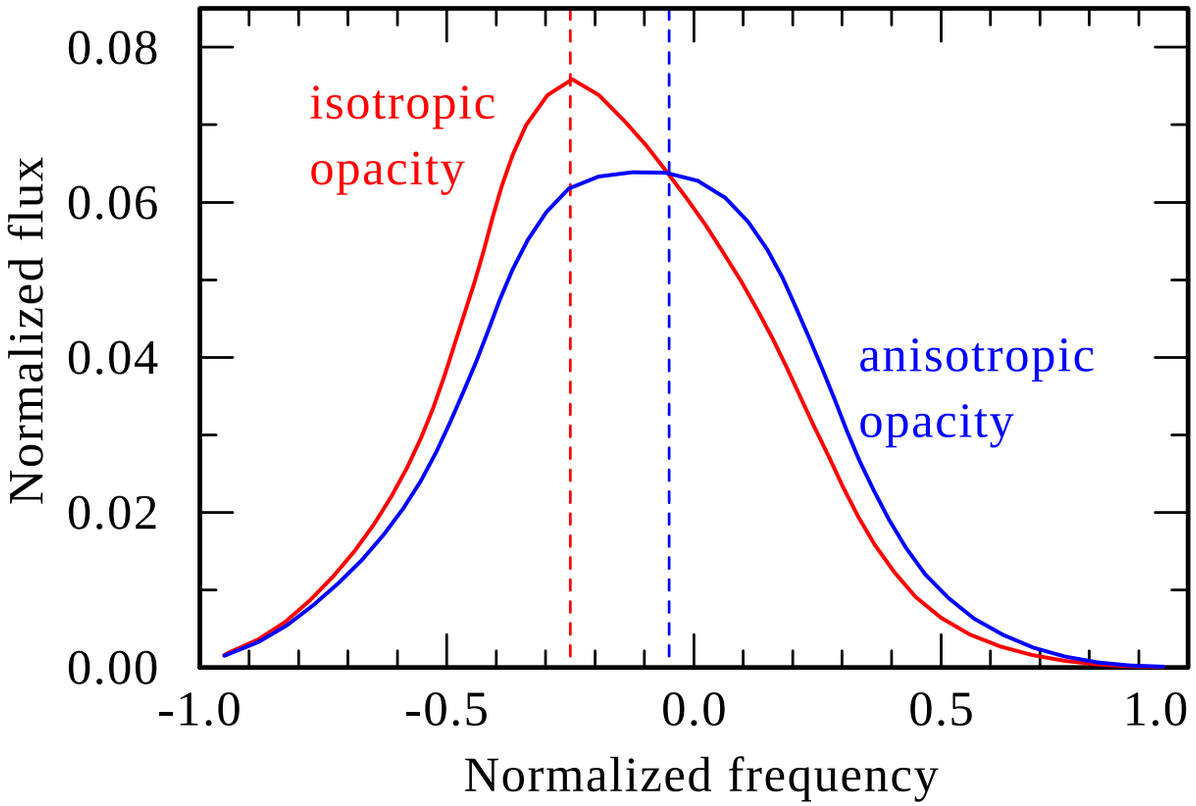
$$\tau_\nu = n_0 \int_{z=r\mu}^{\infty} \frac{1}{\mu v(r)} (1 - \mathrm{e}^{-\tau_\nu^{\mathrm{cl}}})\, dr$$

Pancakes

$$\tau = n_0 \int_{r}^{\infty} \frac{1}{v(r)} (1 - \mathrm{e}^{-\tau_\nu^{\mathrm{cl}}})\, dr$$

- In case of optically thick oblique clumps the optical depth within line does not depend on μ. The resulting lines are symmetric
- In case of optically thick spherical clumps the optical depth within line depends on μ. The lines are skewed.

Line profile depends on the clump shape



- Balls: To get symmetric lines (as observed) the large separation between clumps is requered (Owocki & Cohen 2006 exsersize).
- Pancakes: The lines are more symmetric

Cross-section of a ball does not depend on the orientation, i.e. conceptually similar to atomic cross-section. Therefore emergent line profiles are essentually similar between smooth and clumped models. Oblique clumps result in characteristically different line profiles.

Model line profiles

- Model line profile is fully specified when the following parameters are known:

  mass-absorption coefficent ← PoWR

  stellar parameters ← PoWR

  X- ray line emission region ← X-ray spectra:He-like ions

  fragmentation frequency ← dynamic flow time $n_0 = \frac{v_\infty}{R_*}$

  Clump cross-section ← pancakes

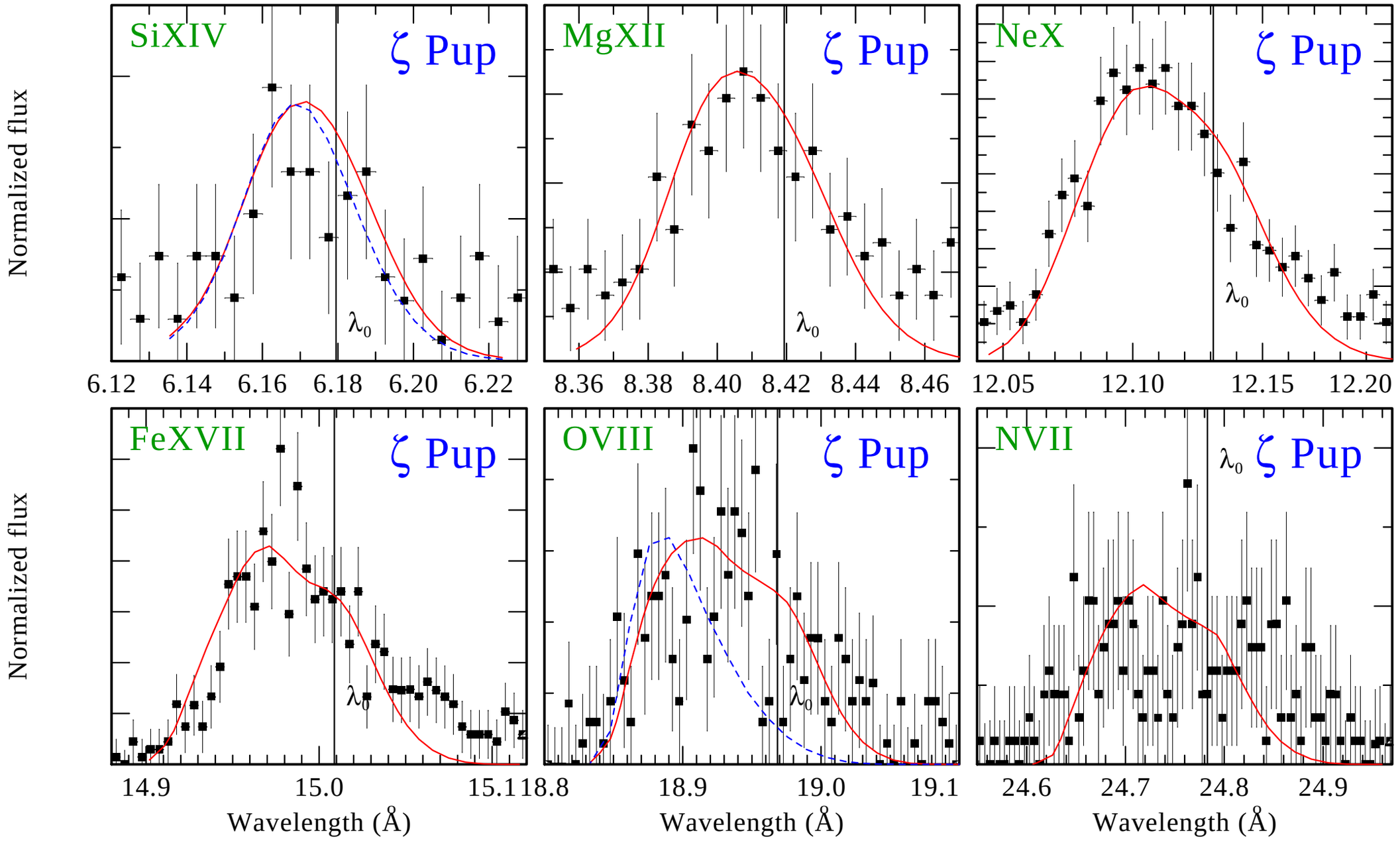
- Thus model line is **FULLY** specified, with no free parameters left!

- Calculate PoWR model for each star

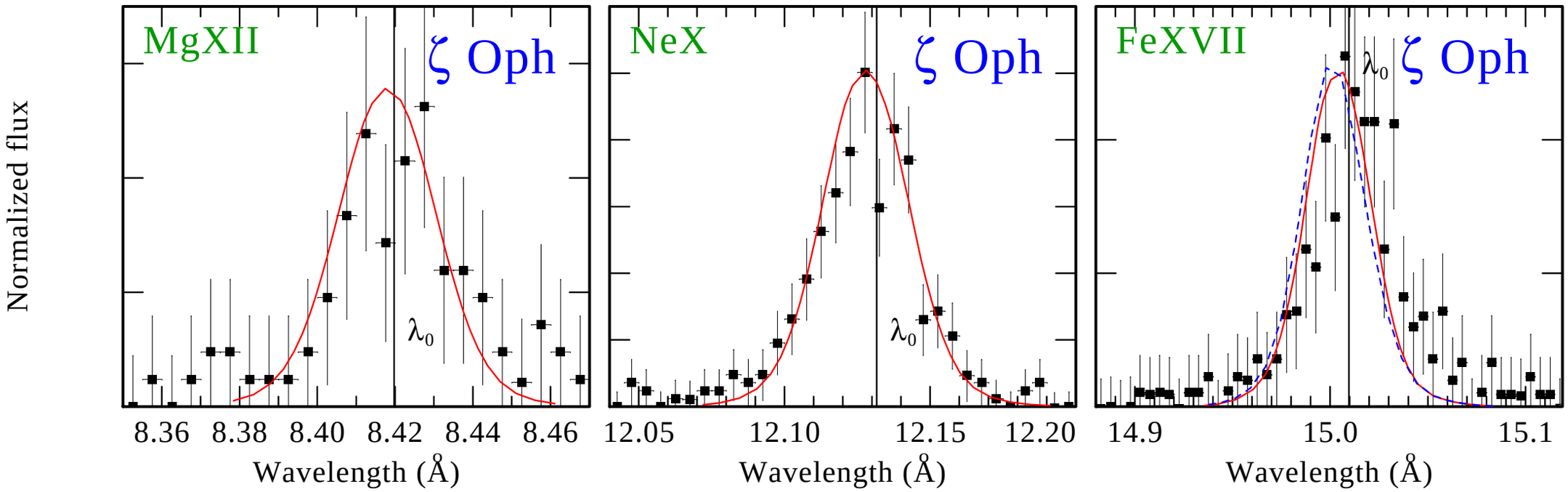
- Calculate model line for each species observed with reasanble S/N

- Compare with the observed lines in each program star

Observed and model lines of ζ Puppis (no fitting!)



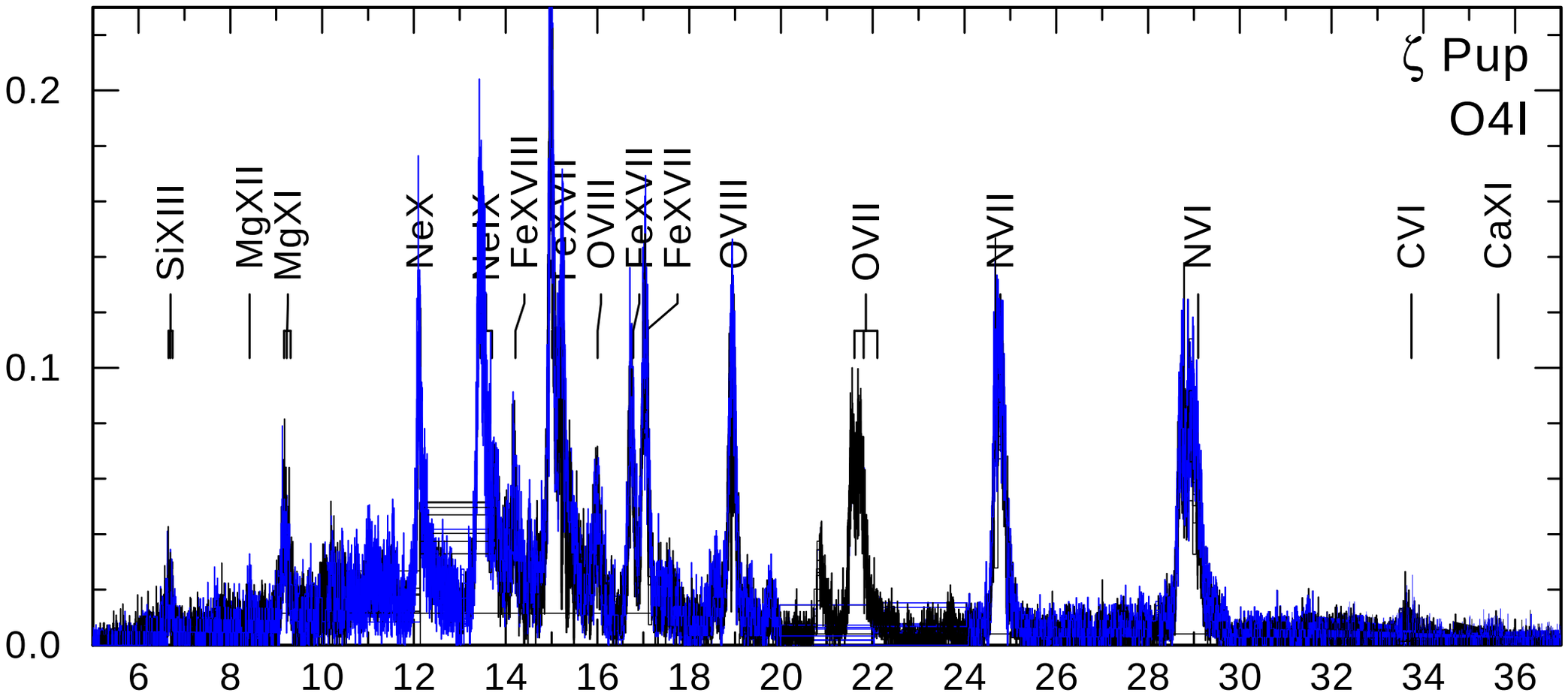
Observed and model lines of ζ Oph (no fitting!)



- Star with very weak wind, $\dot{M} < 10^{-8}$.
- The absorption is not importnat, pure emission lines
- Sensitive to the velocity law, here β=1.5
- Fastest rotator among O stars, Oe type.

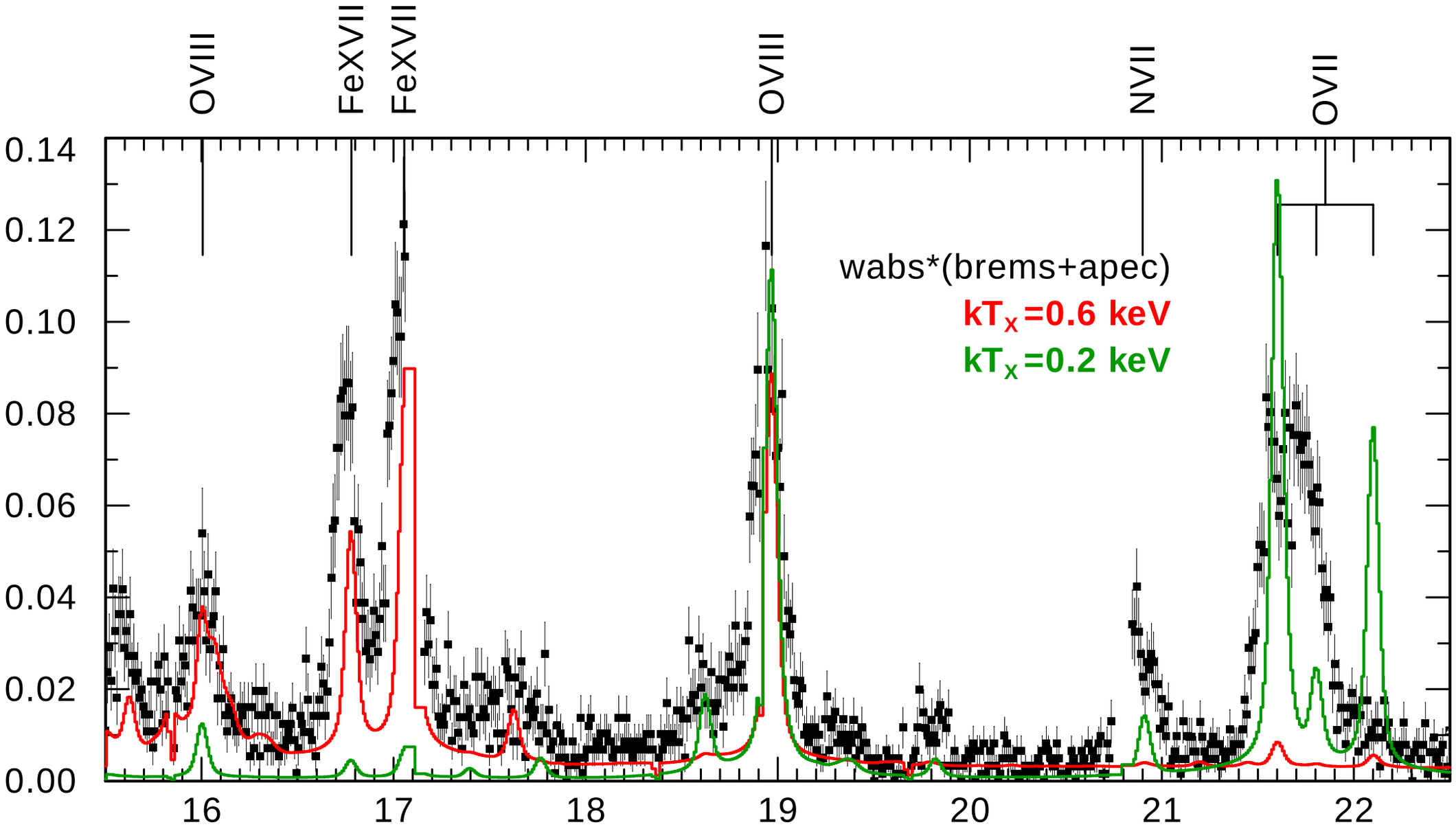
No line flux is calculated, major setback

XMM-Newton five day exposure (470ksec) ζ Pup



- RGS on board of XMM is softer than HETGS on board of Chandra
- Non-continious observations

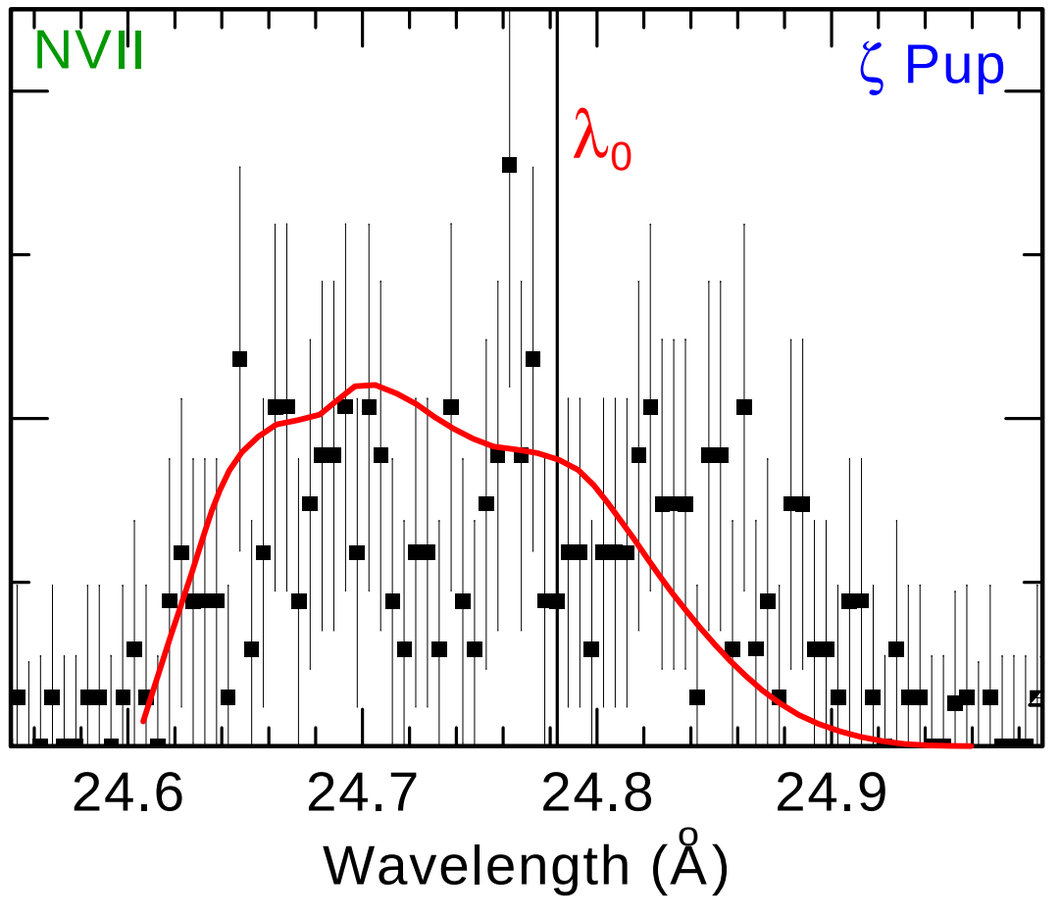
Spectrum: non-isothermal CIE (lines + continuum)



- Continuum: free-free continuum (Kahn+'01, Oskinova+'06)
- Spectral fits: EM of continuum model ≈ EM of line model

Tale of NVII line in ζ Pup spectrum I. Different shape

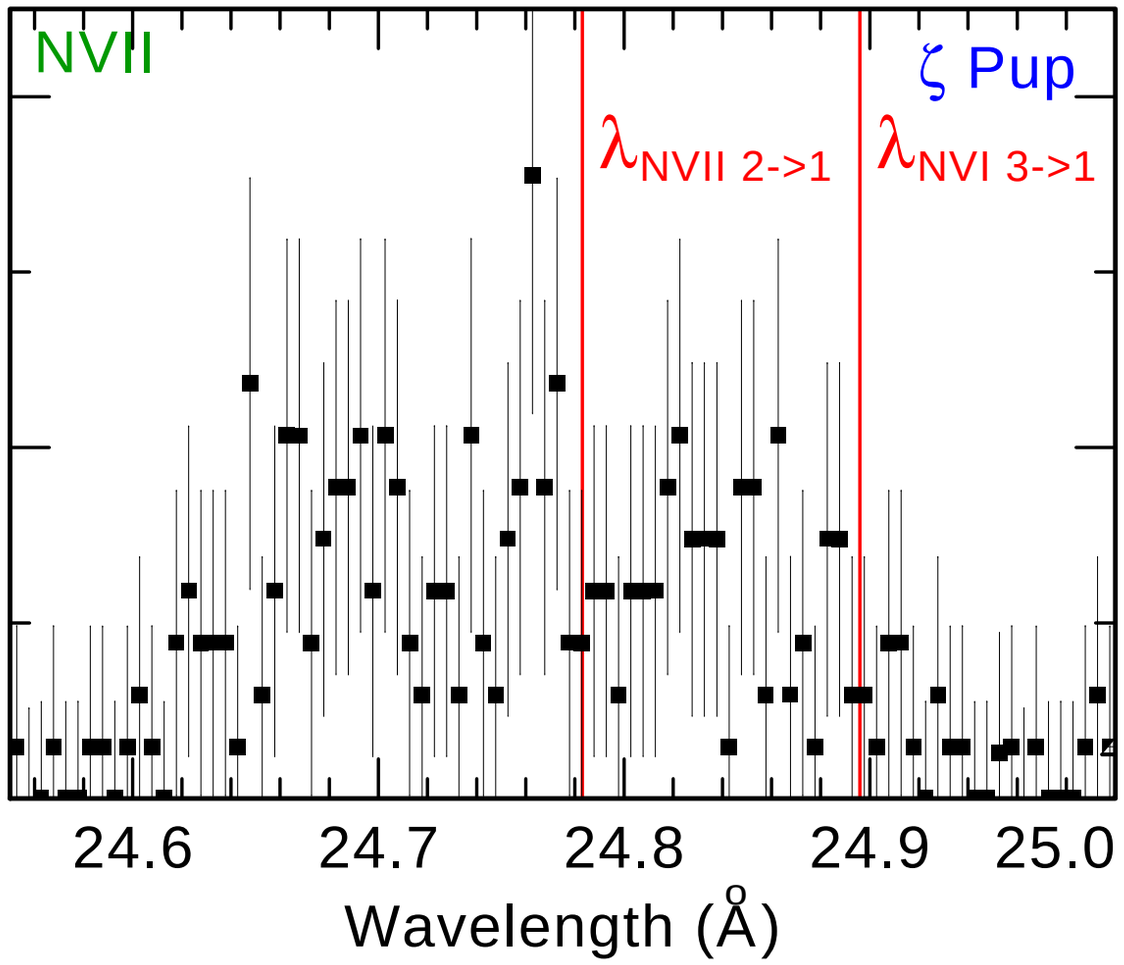
- MEG, RGS → box-like: different from others (Kahn+'01, Cassinelli+ '01, Oskinova+'06)



- Cannot be fitted as coming from wind acceleration zone.
- Far in the wind? Structure?

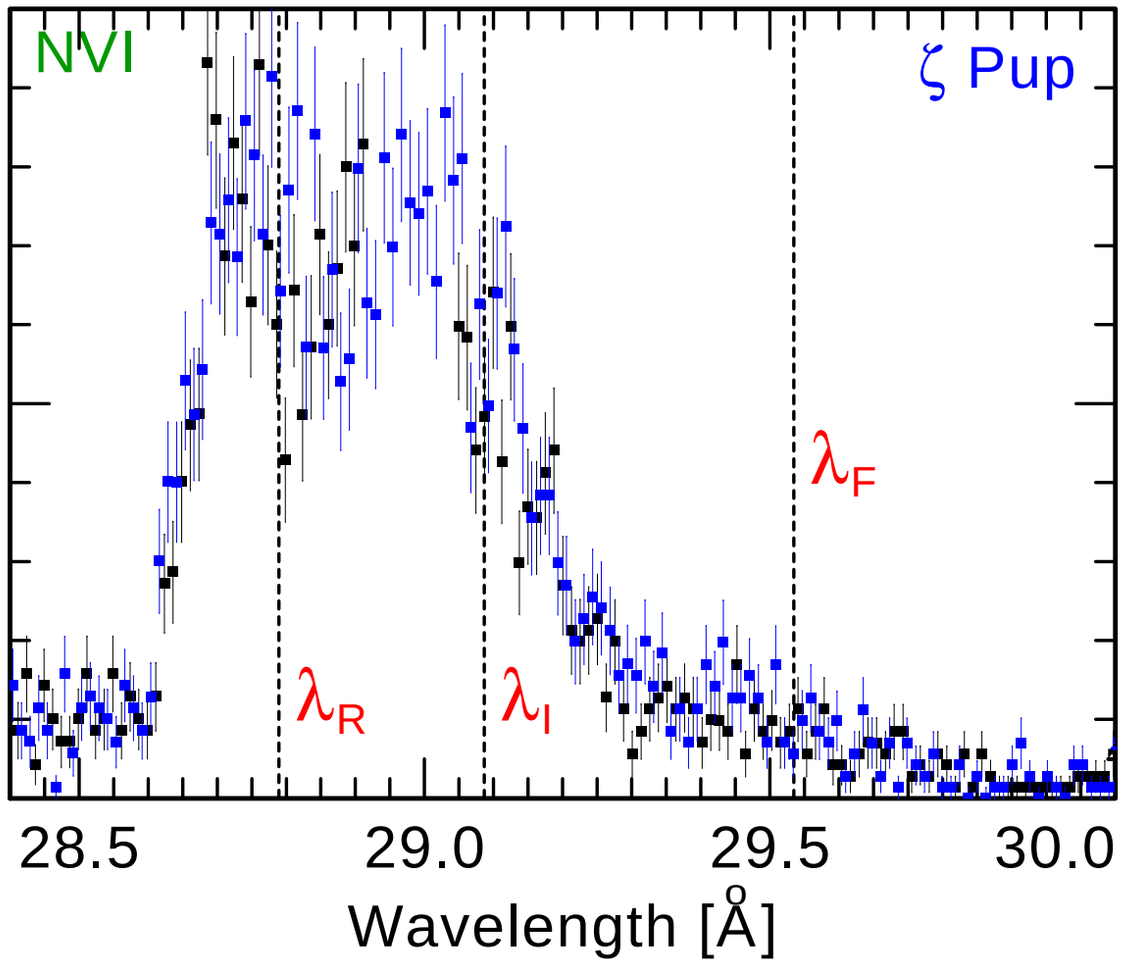
Tale of NVII line in ζ Pup spectrum II. Blend?

- Pollock & Raassen ’06: N VII blended with N VI



- Evolved ζ Pup: overabundant nitrogen
- APEC/CIE: Ratio of N VII and N VI sensitive to the temperature
- Is the temperature correct?

Tale of NVII line in ζ Pup spectrum III. Temperature

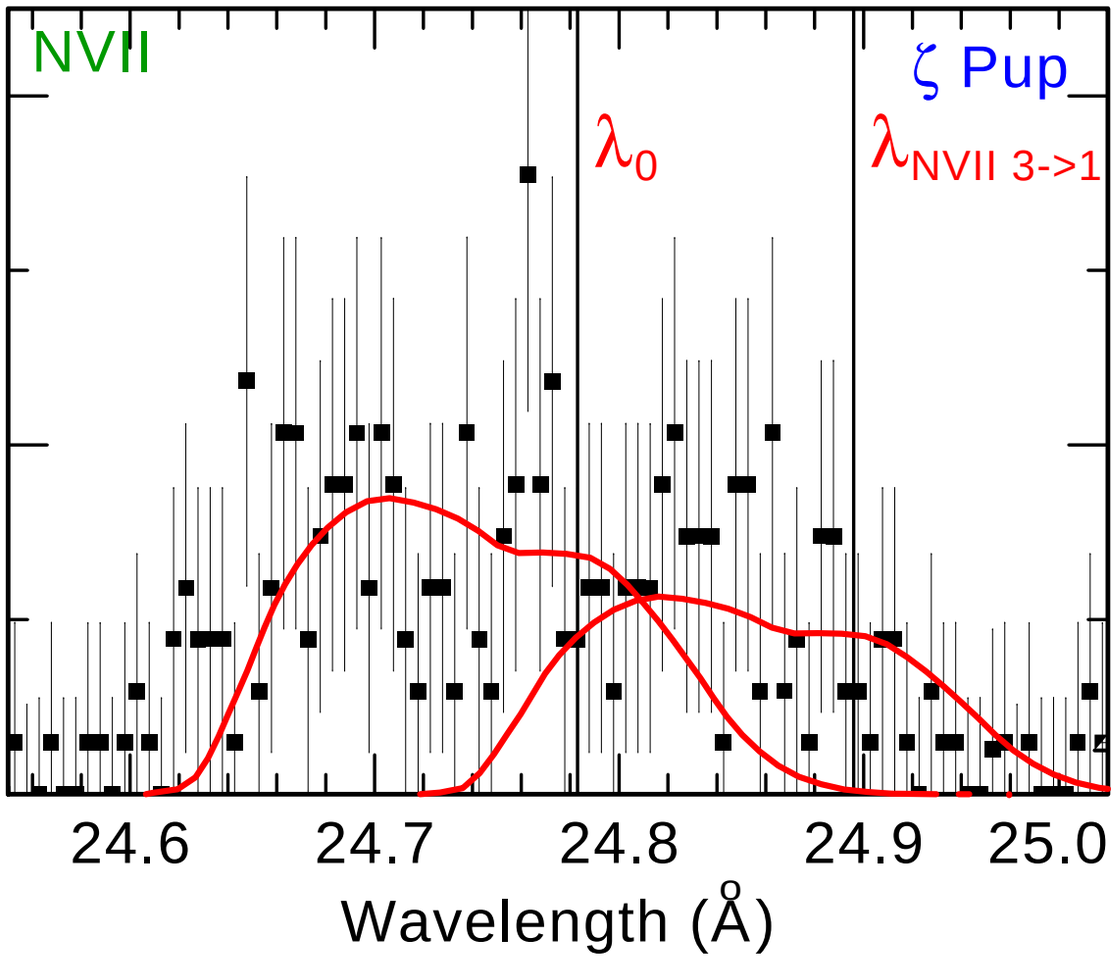


RGS
~ 400 ksec

- Line flux ratios: $R = 0.16 \pm 0.03;\ \ G = 1.1 \pm 0.1$
- CIE: Temperature 10^6 K
- CIE/APEC emissivities:
  intensity ratio N VI λ 24.90Å ≈ 0.5× N VII λ 24.78Å at
  $T = (1 \pm 0.05) \cdot 10^6$ K

Tale of NVII line in ζ Pup spectrum IV. Fit

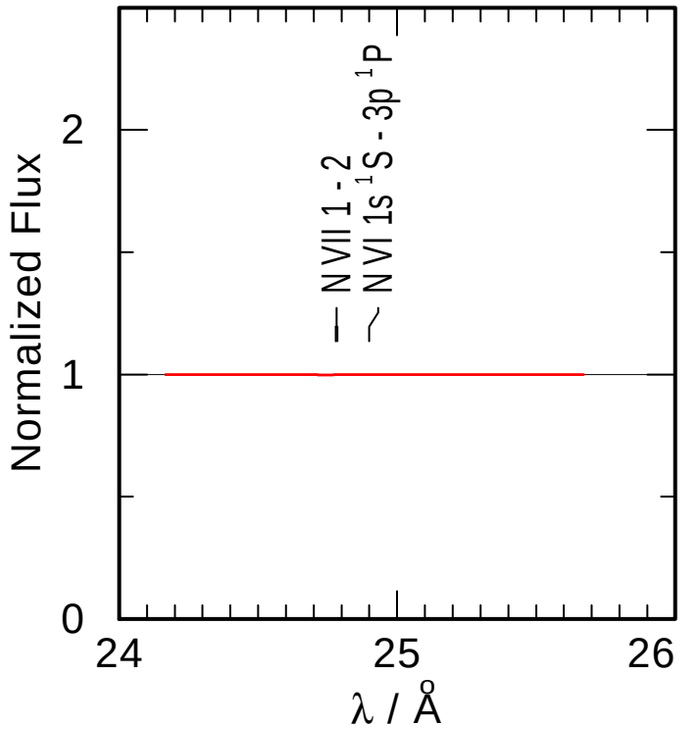
- **Fine tuned agreement between resonace line fitting and fir analysis based on assumption of clumped stellar wind and CIE plasma**



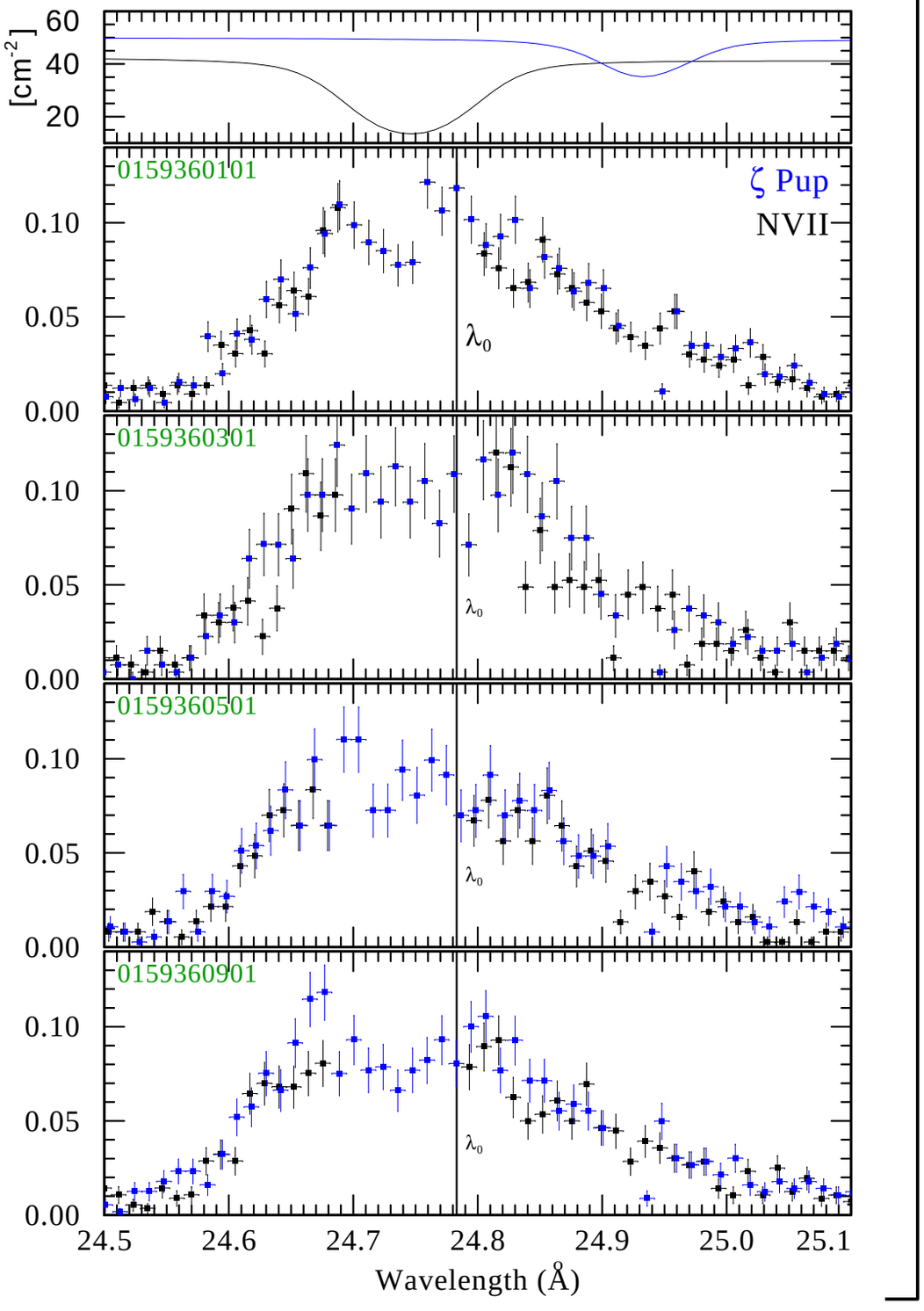
- Line fitting: ratio of lines 0.66 $\Rightarrow T = 1.1 \times 10^6$ K
- Fitting of the blend! But: Mind the gap (Kahn+'01, Oskinova+'06).

Tale of NVII line in ζ Pup spectrum IV Cool wind structure

- The line has structure (variable?)
- Discrete absorption components: moving DACs in all O stars
- Can NVII be formed in cool wind, by i.e. autoionization of NV ?

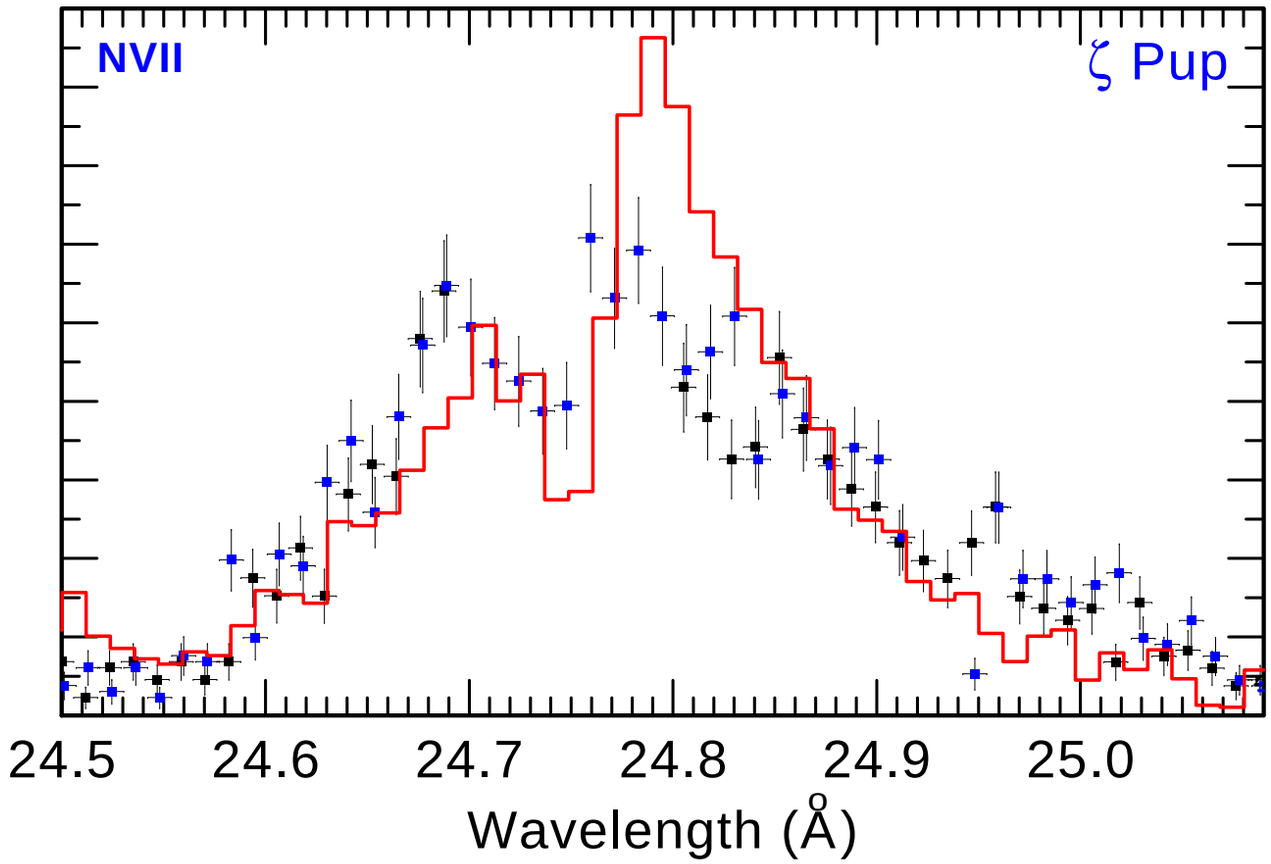


- **No NVII in cool wind!**



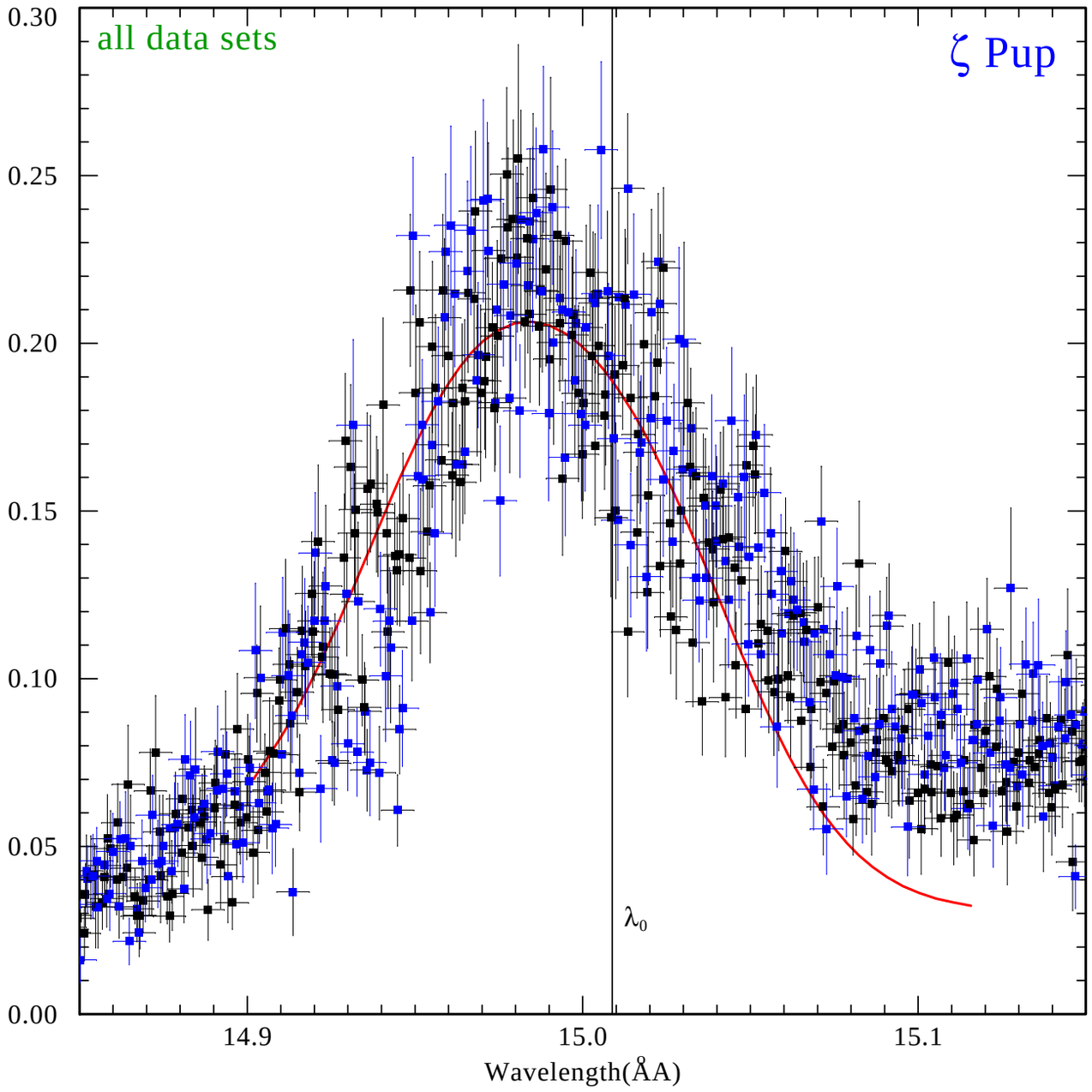
Tale of N VII line in ζ Pup spectrum V. Self-absorption

- **The structure seen in the X-ray emission line of N VII is typical for optically thick lines observed in winds**



- ζ Pup: high nitrogen; N VII is dominant ion (CIE plasma)
- Same line shape seen in opt. spectra (red: HeII λ5412 in WR 2)

→ Full RT is needed (also for Mg XI + O VI et cet.)

Stochastic variability

- The same scatter as in this FeXVII line is seen in all other lines and continuum. This is an evidence of stochastic variability.