Clumping in Hot Star Winds
W.-R. Hamann, A. Feldmeier & L.M. Oskinova, eds.
Potsdam: Univ.-Verl., 2008
URN: http://nbn-resolving.de/urn:nbn:de:kobv:517-opus-13981

Discussion: X-rays

Moderator: Joachim Puls

Feldmeier: David, why is always exactly the porosity length $h = 0$ in your confidence plots? This is statistically significant. One would instead expect a distribution around $h = 0$.

Cohen: The mean value is not significant, but only the error interval.

Feldmeier: The wind fragmentation model was invented to help understand the data. Now you say it is of no use. How can this be understood physically?

Cohen: Because fragments are wrong. It should be Rayleigh-Taylor fingers like in Dessart & Owocki (2003, A&A).

Feldmeier: But that latter model is problematic because the radiative transfer is only 1D there, not accounting for the lateral line force.

Cohen: Rayleigh-Taylor breakup of radially compressed shells seems physically plausible to me. Fragmentation while the fragments of the shells retain their radial compression and lateral coherence seems less likely to me, but certainly not out of the question.

Oskinova: I am worried whether it is methodologically correct to use fitting software in order to discriminate between models. Fitting software is a wonderful tool to infer parameters for a given underlying model. However, it is unclear to me how to treat the situation when a physically unsound model would provide a statistically good fit to observations, e.g. due to a large number of free parameters. I would say that good fitting statistics *per se* may be necessary, but it is certainly not sufficient to physically validate the input model.

Pollock: The HMXBs show me at least that there is no chance that you can see in X-rays to the other side of an O star. These accreting neutron star X-rays sources are always very heavily absorbed. As they emerge from eclipse the X-ray reach the observer first through the upper layers of the companion star and then through the lower layers of the wind. The column density falls from $10^{24}\,\mathrm{cm}^{-2}$ or more but never gets lower than $10^{22}\,\mathrm{cm}^{-2}$.

Oskinova: The column density is largest when we are directly looking at the neutron star because of the absorption column. In order to emit, a neutron star should accrete. Therefore, talking about direct component in the spectra of HMXBs, I would say we always would see the neutron star absorbed, otherwise it would not be X-ray active.

Prinja: It is interesting to note that in terms of large-scale structure (e.g. DACs), the UV time series show that the coherence of the structures evident is greater as you go from early O stars (like ζ Pup), to mid-O (like ξ Per) and finally early B stars (such as HD 64760). Perhaps this behavior should also be examined in connection to any pattern in the shapes and shifts in the X-ray profiles (e.g. in the survey of Waldron & Cassinelli, 2007).

Hillier: I agree wholeheartedly with Joachim Puls that taking another look at the soft X-ray band for ζ Pup would be extremely beneficial. There are some interesting issues that could be looked at. Does He III recombine? Is porosity important for seeing the soft X-rays? Do the soft X-rays originate at larger radii? I also have a question regarding the X-ray properties of O stars. ζ Pup seems to be the prototypical example of what we expect the X-ray spectrum of an O star to look like. Can someone address the other O stars, and their X-ray properties?

Hamann: The radius where the X-ray emitting plasma is located is determined by the f/i line ratios of He-like ions. This diagnostic yields the dilution factor of the UV radiation field that depopulates the metastable levels. Thus the results and their uncertainty depend on having a good model for the stellar UV radiation field. Which model did you use, and it this a major source of uncertainty?

Cassinelli: We considered both the Kurucz and Hubeny atmospheric models. There was some difference in the f/i radii, but not a large amount. If the wavelength of the f-i transition were to fall at the wavelength of a broad FUV or EUV line, that would make the R_{fir} value smaller, and if the wavelength were at an emission line, R_{fir} would be larger. But the conclusion that the high ions form near the star, and that low ions can form at all radii is a good one.

Leutenegger: X-ray emitting regions formed far out in the wind cannot cool efficiently, so X-ray emission can persist to large radii. Also, since most O stars observed in X-ray have lower mass loss rates than ζ Pup by a factor of a few, and since the highest values of τ_* I measure in ζ Pup are of order four, the highest values of τ_* measured in other stars should be of order unity. This produces nearly symmetric profiles. Thus, it is not surprising that we see relatively narrow, almost symmetric profiles from most O stars.

Hamann: Stan Owocki doubts whether porosity plays a role in the continuum absorption of X-rays, but he agrees that its effect can reduce the P v resonance line. I want to point out that a similar clump separation (of the order of one stellar radius) has been aplied in our X-ray modelling as well as in our recent modelling of the UV and optical lines. The only difference is that shell fragments ("pancakes") have been adopted for the X-ray attenuation, while the recent line-formation study is still restricted to isotropic clumps.

Oskinova: In our models of X-ray line profiles we assumed that a clump is "launched" once per flow time in each radial direction. Thus, the clump separation at v_∞ is one stellar radius. But in the wind acceleration region, the clump separation is much smaller. This is a plausible choice of parameters and is supported by observations. In denser winds, because our models conserve mass, these clumps are not necessarily optically thin, therefore smooth wind models are not adequate to model X-ray lines. The assumption of anisotropic opacity within clumps, e.g. that clumps are shell-fragments, leads to more symmetric line profiles compared to the isotropic case. Therefore, X-ray emission line profiles provide a wonderful tool to gain insight into the clump geometry.

Runacres: Paco, I think it is important to realize that you do not know whether the clumping factor *disappears* in the radio formation region. You may know that the clumping factor is *lower* in the radio formation region than in the region close to the star (by comparing the radio continuum with other diagnostics), but you do not know whether it is zero. This means, as was mentioned before by Joachim (Puls), that the $\dot{M}$ we derive actually the largest possible value. The actual numbers depend on the residual amount of clumping in the radio formation region.

Leutenegger: The He-like profiles from my paper support Joe's idea of seeing down to the radius of optical depth unity, but for a lower mass loss rate than Cassinelli & Waldron claim. This is just because they assume a single radius of formation, while we fit the entire profile with a model that accounts for f/i as a function of radius.

Feldmeier: Refering to Mark: it should be easy to replace the current approximation of a constant clumping factor with radius, or of some simple power law, with a more realistic law obtained from numerical simulations. The line-driven instability operates mostly in the accelerating part of the velocity law where de-shadowing occurs, and it does not form significant new wind structure at large distances from the star where the wind speed is almost constant. There are, therefore, only two competing processes that determine the clumping factor at large radii: clump-clump collisions in the stochastic clump ensemble; and pressure expansion of clumps.