Feb. 28, 2006

Dear Lida, Achim, Wolf-Rainer:

I just wanted to follow up briefly on the recent notes I sent on my ideas for comparing isotropic and anisotropic porosity models. My notes were based largely on comments Lida made in her Feb. 7 email, without focussing too much on your most recent preprint of fitting X-ray profiles with your fractured wind model. Now I've had a chance to look more carefully at that preprint, and I have some questions and comments on this.

First, you can see from my notes that one potential connecting point between our analyses is to recognize that your "fragmentation frequency" n_o can be used to define an asymptotic separation distance, $h_\infty \equiv v_\infty / n_o$. When scaled in terms of the stellar radius R, this separation can also be written as

$$\frac{h_\infty}{R} = \frac{v_\infty}{R n_o} \equiv \frac{n_{exp}}{n_o} \,, \tag{1}$$

where $n_{exp} \equiv v_\infty / R$ is the wind expansion rate, given by the inverse of the expansion time for the wind at terminal speed to flow through a stellar radius.

So I guess one comment I have on your paper is that the practice of simply quoting the fragmentation frequency in inverse seconds makes it rather hard to relate this to something physically associated with the various stars. If you prefer not to characterize things in terms of asymptotic separation length, perhaps we could relate the fragmentation frequency to this characteristic wind expansion rate, $n_o < n_{exp}$.

In order to get significant effects in symmetrizing the line profiles, one actually has to use a quite low fragmentation frequency, typically of order or somewhat lower than the expansion frequency, $n_o < n_{exp}$. This is equivalent to the point that the separation scale, or "porosity length", must be quite large, on order of the stellar radius or more, $h_\infty > R$.

I personally prefer the length formulation because it tells you immediately that there have to be large spatial gaps between the individual clumps, making the point that this is indeed a key requirement of a strong porosity effect.

Anyway, the above eqn. (1) shows how the length vs. frequency points of view are connected through the relevant ratio. So I went through your paper to translate the quoted fragmentation frequencies into this ratio for each of the four stars, using the data given in your table 2 for R and v_∞. For the four stars ζ Pup, ζOri, ξ Per, and ζOph, I find respectively values of $h_\infty / R = n_{exp}/n_o = 1.04$, 1.25, 3.22, and 2.50.

The key point then is that in all cases, the ratio is above unity, indicating a quite low fragmentation frequency, or equivalently quite large radial separations between clumps.

As emphasized in our recent OC06 paper, I feel it is unlikely that structure arising from the line-driven instability will have this large a separation scale. Perhaps that interpretation of LDI models is somewhat open to debate, but it would worthwhile if we could all agree that strong porosity effects require such large scales.

In your paper, you do offer an alternative characterization of the fragmentation frequency, namely the number of clumps, defined in your eqn. (7) as

$$\langle N_r \rangle = n_o \int \frac{dr}{v(r)} \, . \tag{2}$$

But what rather confuses me is that you don't give any limits to the integration here, so I'm not quite sure what to make of the numbers you quote on this. For a simple $\beta = 1$ law, the above integral gives

$$\langle N_r \rangle = \frac{n_o}{v_\infty} \left[r + R \log(r/R - 1) \right] . \tag{3}$$

This can be made arbitrarily large by starting close to the surface $r \to R$, or extending out to large enough radii, $r \to \infty$.

In various points in your discussion you quote presumed "formation radii" for the X-ray line profile. Presumably, you mean by this the range of radii for X-ray emission. And perhaps then the $< N_r >$ numbers you quote are meant to be the number of radial clumps in that range (though the numbers seem too high for that). But even if that were what is meant, that doesn't seem right, since the attenuation of X-rays can occur for regions well outside the range where they are emitted.

This leads me to another question I had, namely regarding your apparent use of eqn. (12) to evaluate the ray optical depth for all locations in the wind, under the apparent assumption that the clumps are essentially always optically thick. In my notes, I had to identify the wind location where the clumps become thick along a given ray, and then broke up the integral accordingly, as in my eqns. (11)-(14). My fig. 1 shows the location of the transition between optically thin to thick clumps for a given location z_1 along a ray with fixed p. Note that this depends on the product of the smooth wind optical thickness τ_* times the separation length h_∞.

A concern here is that, by assuming the form given in your eqn. (12), one is in effect using a *reduced* opacity even in places where it should not apply, i.e. where the clumps are optically thin, and thus have no way to "self shadow" material. This could skew the results toward a more transparent or "porous" wind than is actually appropriate.

To be honest, I don't know how serious this potential error might be for the model cases you compute. But it seems it is something that should be checked.

Anyway, I hope my notes will make it possible for us to reconcile our approaches. Indeed, I would suggest that that it would be a good idea for us each to compute profiles for a few sample cases, based on common assumptions for both the emission model and the porosity formulation, for example your pancake model using your "velocity stretch" form for the separation scale $h = h_\infty(1 - R/r)$.

Could you, for example, produce profiles for some or all of the cases given in the right column of fig. 2 in my notes?

Or, do you have some specific model cases that you would like me to compute using my formulation of your pancake porosity model?

Let me know if you would be interested in such direct comparisons.

Stan