Towards a unified model

James Matthews

July 13, 2017

We want to produce spectra that resemble quasars in terms of their emission line equivalent widths at a range of inclinations, especially low ones. Let us begin by defining the equivalent width, EW, at a given angle, θ, in terms of luminosities

$$\mathrm{EW}(\theta) = -\int 1 - \frac{L_\lambda(\theta)}{L_C(\theta)} d\lambda \tag{1}$$

where the integral is across the line profile and the subscript C denotes continuum and the minus sign goes against convention by ensuring positivity for emission lines. If the continuum is constant across the line profile we can then write

$$\mathrm{EW}(\theta) = 1/L_{C,\lambda_0}(\theta) \int L_\lambda(\theta) - L_C(\theta) d\lambda \tag{2}$$

Since the integral is now just the escaping line luminosity at that angle, we have

$$\mathrm{EW}(\theta) = \frac{L_{ul}(\theta)}{L_{C,\lambda_0}(\theta)} \tag{3}$$

where L_{ul} is the escaping line luminosity at that angle for transition $u \to l$.

Now let us illuminate some plasma that subtends angles $\theta_{\min} \to \theta_{\max}$ to the source, defined from the polar axis. The source has total luminosity integrated across all angles and wavelengths of L_{bol}. The plasma intercepts a fraction of this radiation f_{illum} given by

$$f_{\mathrm{illum}}(\theta_{\min}, \theta_{\max}, \epsilon) = \frac{1}{2\pi} \int_0^{2\pi} d\phi \int_{\theta_{\max}}^{\theta_{\min}} \epsilon(\theta) d\theta. \tag{4}$$

where $\epsilon(\theta)$ is the "angular emissivity function". This function is a constant in the case of an isotropic source, and $\cos\theta$ for a foreshortened disc. The 2π rather than 4π is because we integrate assume symmetry above and below the disc plane. We can also define a line reprocessing efficiency, η_{ul}, which governs how much of the illuminating luminosity is converted into (isotropic) line emission, i.e.

$$\eta = \frac{L_{ul}(\theta)}{f_{\mathrm{illum}} L_{\mathrm{bol}}} \tag{5}$$

η can be calculated from my simulation grids and tends to be about $0.06 - 0.1$ for Lyman alpha. I adopt 0.06 below. We can now substitute into our expression for EW to give

$$\mathrm{EW}(\theta) = \eta L_{\mathrm{bol}} \frac{1}{L_{C,\lambda_0} \epsilon(\theta)} \frac{1}{2\pi} \int_0^{2\pi} d\phi \int_{\theta_{\max}}^{\theta_{\min}} \epsilon(\theta) d\theta. \tag{6}$$

$$\mathrm{EW}(\theta, \theta_{\min}, \eta) = \eta L_{\mathrm{bol}} \frac{1}{L_{C,\lambda_0} \cos(\theta)} \left[1 - \sin(\theta_{\min})\right] \tag{7}$$

Now we can predict what wind geometry we need. Let's look at Lyman alpha. Our target is EW$=75$Å. Let's adopt $L_{\mathrm{bol}} = 1/2(GM\dot{m})/R_* \approx 2 \times 10^{46}$, $\eta = 0.06$, and read the monochromatic luminosity L_{C,λ_0} from our log spec tot file. The results are shown in Fig. 1, which shows EW as a function of viewing angle for different wind geometries.

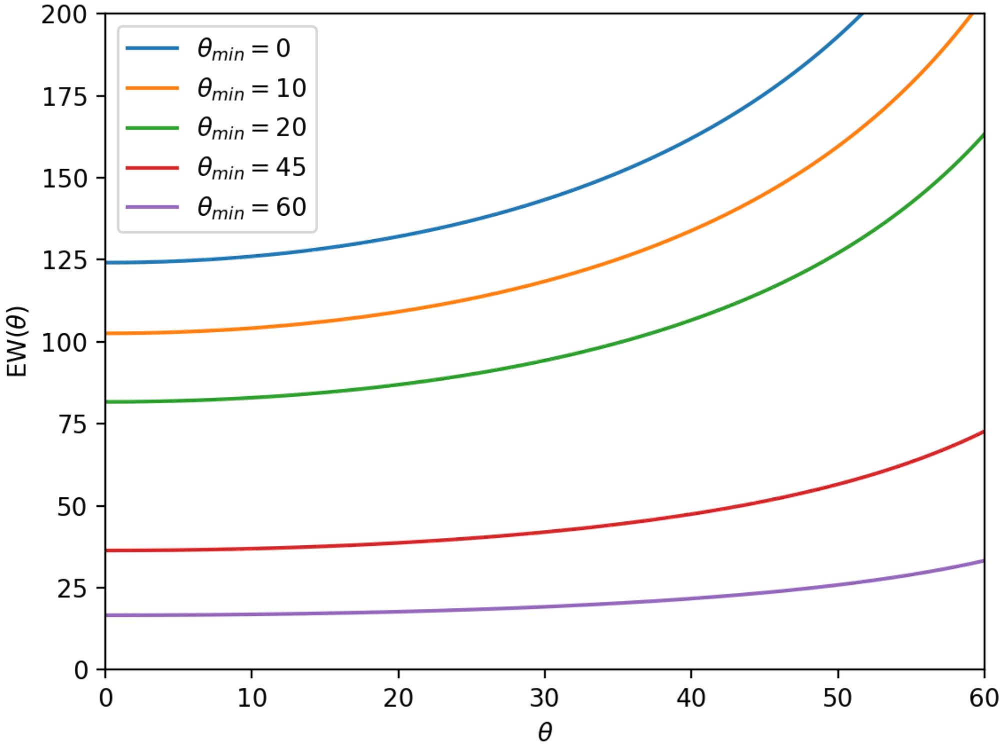

Figure 1: EW as a function of viewing angle for different wind geometries.