Hot star wind mass-loss rate predictions from global CMF models

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Abstract: We provide mass-loss rate predictions from global (unified) wind models. The models are calculated for main-sequence, giant, and supergiant O stars at galactic, LMC, and SMC metallicities. The models solve kinetic equilibrium (NLTE), comoving-frame (CMF) radiative transfer, and stationary hydrodynamic equations from the photosphere in the hydrostatic equilibrium to the supersonic wind. We predict wind mass-loss rates as a function of stellar luminosity and metallicity. The derived mass-loss rates are by a factor of about 2–5 lower than commonly used predictions. The difference is caused by inclusion of detailed CMF line blocking in far-UV region. The line blocking affects the emergent flux in the far-UV region leading to the decrease of the radiative force that can not be accounted for in single-line Sobolev approach. Our predicted mass-loss rates agree with the mass-loss rates derived from observation of near-infrared and X-ray line profiles and are slightly lower than mass-loss rates derived from combined UV and Halpha diagnostics.

METUJE global wind models

Our models predict wind structure and derive wind mass-loss rate from the basic stellar parameters (i.e., the effective temperature, mass, radius, and metallicity). The model assumptions are (Krtička & Kubát 2017):

- spherical symmetry, stationarity,
- stellar photosphere and wind treated in global (unified) manner,
- we solve the same equations in the photosphere and in the wind,
- radiative transfer solved using the comoving-frame (CMF) radiative transfer equation taking into account all transitions relevant in hot stars,
- ionization and excitation state derived from the statistical equilibrium (NLTE) equations using atomic data from the Opacity and Iron Projects,
- bound-free radiative rates in NLTE equations derived from the CMF radiative field and bound-bound rates derived using Sobolev approximation,
- the line radiative force calculated using the solution of the CMF radiative transfer equation,
- the condition of radiative equilibrium used to derive the temperature in the photosphere,
- the radiative cooling and heating terms derived using the electron thermal balance method (Kubát et al. 1999) in the wind,
- the equations of continuity, motion, and energy are solved iteratively to obtain the photosphere and wind density, velocity, and temperature structure,
- the most important output parameters are wind mass-loss rate $\dot{M}$, terminal velocity v_∞, and emergent flux H_ν.

Model stars

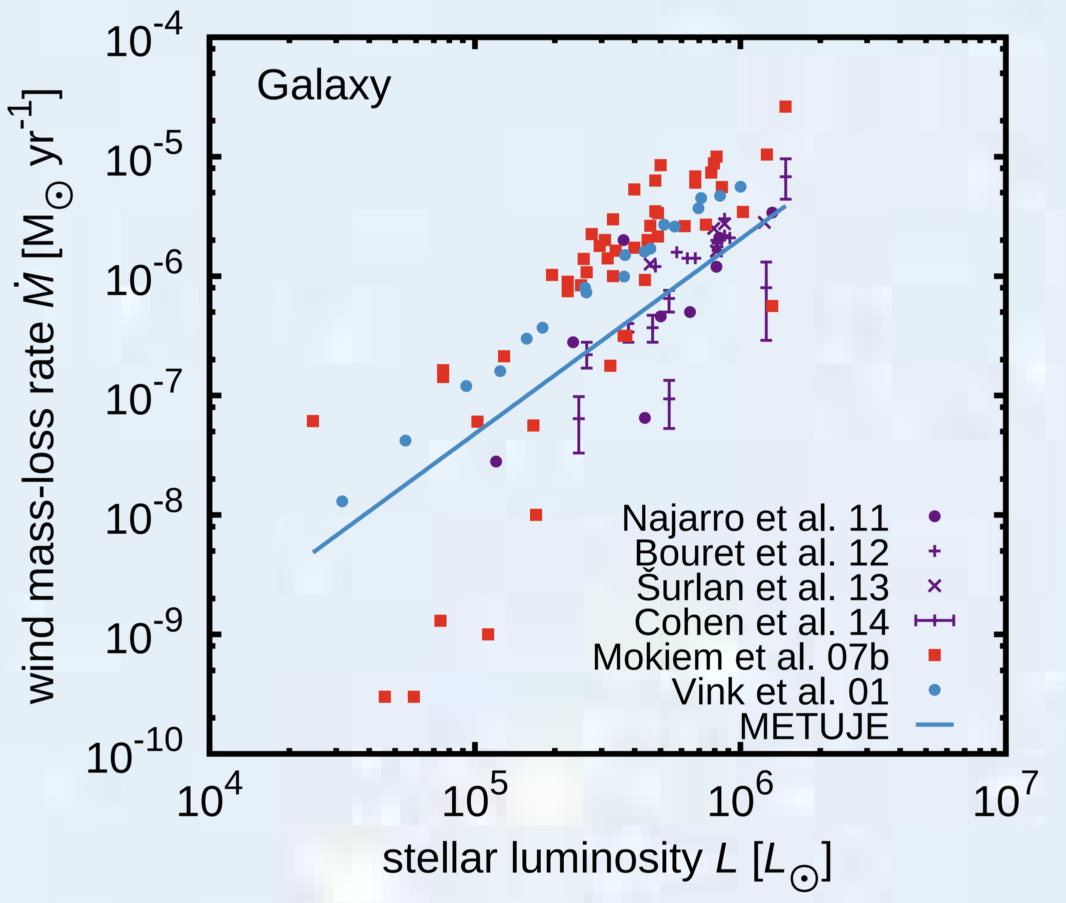
	model	$T_{\rm eff}$ [K]	R_* [$R_\odot$]	M [$M_\odot$]	$\log(L/L_\odot)$
main sequence	300-5	30000	6.6	12.9	4.50
	325-5	32500	7.4	16.4	4.74
	350-5	35000	8.3	20.9	4.97
	375-5	37500	9.4	26.8	5.19
	400-5	40000	10.7	34.6	5.42
	425-5	42500	12.2	45.0	5.64
	450-5	45000	13.9	58.6	5.85
giants	300-3	30000	13.1	19.3	5.10
	325-3	32500	13.4	22.8	5.25
	350-3	35000	13.9	27.2	5.41
	375-3	37500	14.4	32.5	5.57
	400-3	40000	15.0	39.2	5.71
	425-3	42500	15.6	47.4	5.85
	450-3	45000	16.3	57.7	5.99
supergiants	300-1	30000	22.4	28.8	5.56
	325-1	32500	21.4	34.0	5.66
	350-1	35000	20.5	40.4	5.75
	375-1	37500	19.8	48.3	5.84
	400-1	40000	19.1	58.1	5.92
	425-1	42500	18.5	70.3	6.00
	450-1	45000	18.0	85.4	6.08

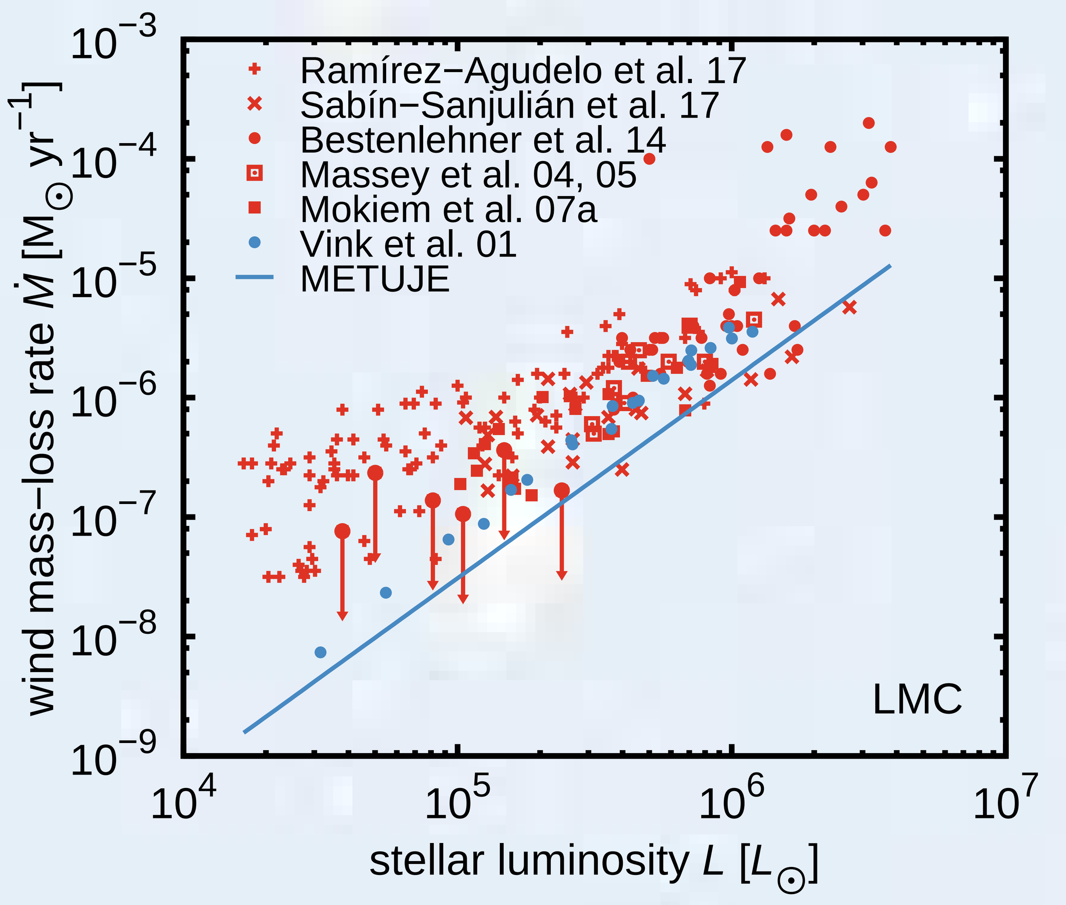
We calculated a grid of global wind models for stellar parameters corresponding to O stars in the effective temperature range $30\,000-45\,000\,$K. Stellar masses and radii were derived using relations of Martins et al. (2005) for main sequence stars, giants, and supergiants. We calculated wind models for three different metallicities corresponding to our Galaxy (with solar mass fraction of heavier element, $Z = Z_\odot$), Large Magellanic Cloud (LMC, $Z = 0.5\,Z_\odot$), and Small Magellanic Cloud (SMC, $Z = 0.2\,Z_\odot$). The solar abundances were taken from Asplund et al. (2009).

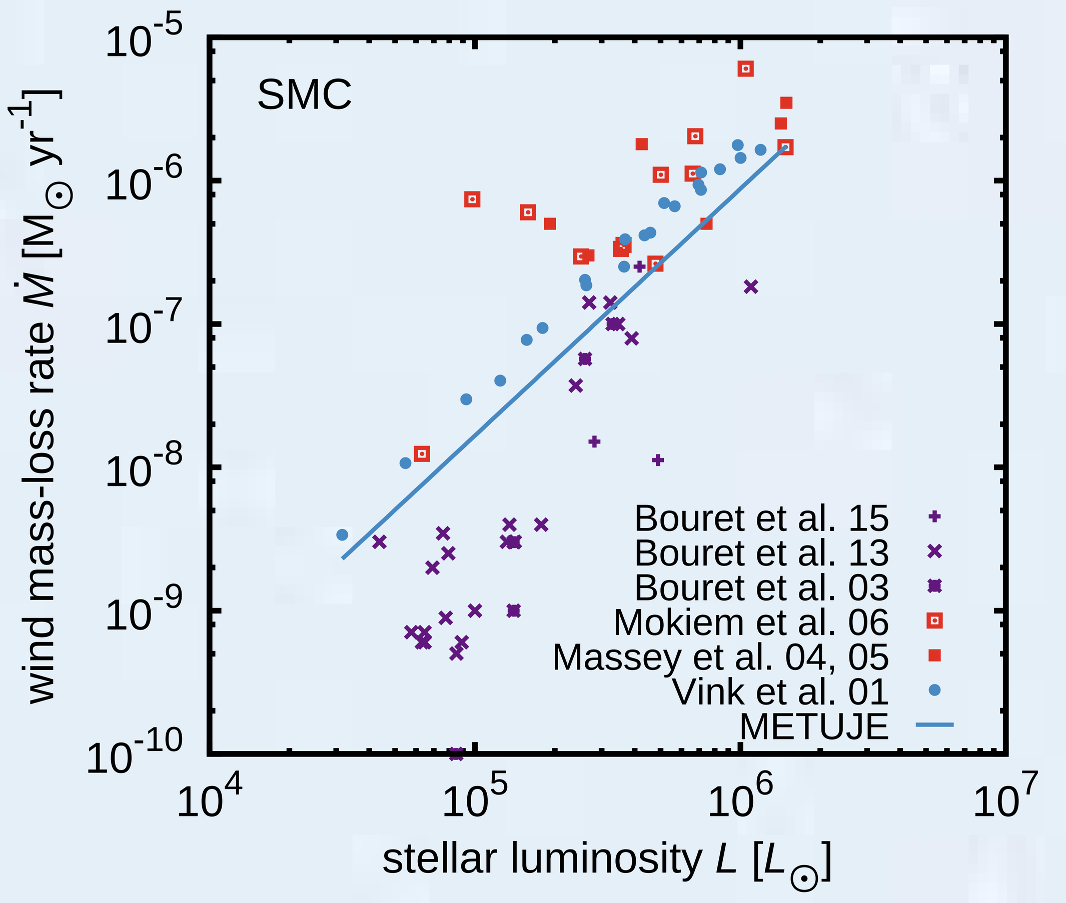
Mass-loss rates

The predicted mass-loss rates can be fitted via

$$\log\left(\frac{\dot{M}}{1\,M_\odot/\mathrm{yr}}\right) = -5.70 + 0.51\log\left(\frac{Z}{Z_\odot}\right) + \left[1.61 - 0.16\log\left(\frac{Z}{Z_\odot}\right)\right]\log\left(\frac{L}{10^6 L_\odot}\right).$$

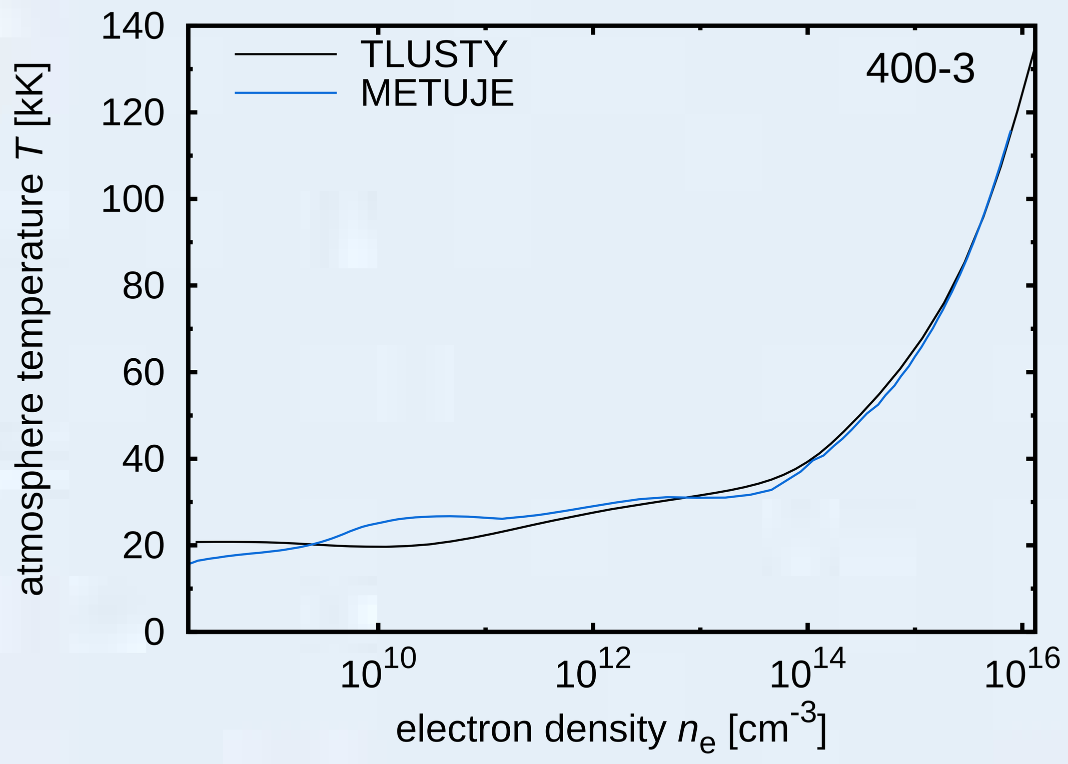




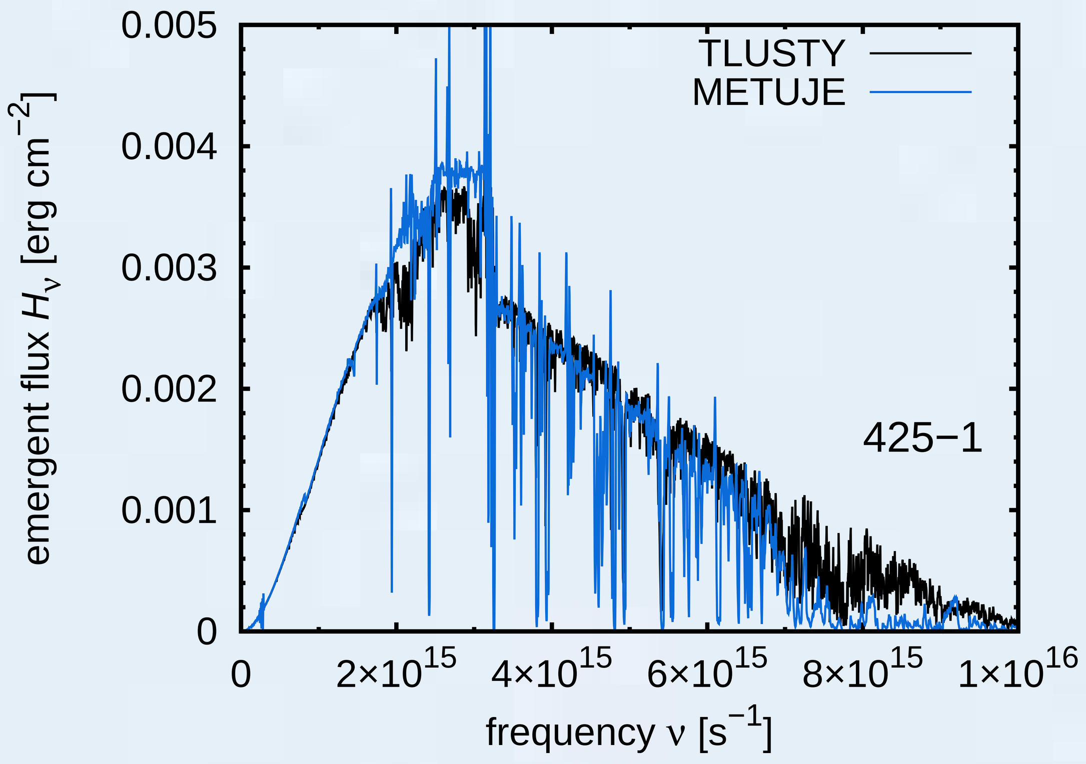


The predicted mass-loss rates (blue line) agree with observational results corrected for clumping (violet symbols). The clumping factor of at least $C_c = 8-9$ is needed to reconcile the Hα mass-loss rates (red symbols) with theoretical predictions. Our estimates are by a factor of $2-5$ lower than the predictions of Vink et al. (2001, blue dots). The reason for the decrease of the mass-loss rates with respect to our previous estimations is a more precise calculation of the radiative force in the CMF and the blocking of the radiative flux for $\nu \gtrsim 7\times10^{15}\,\mathrm{s}^{-1}$ in global models.

Temperature distribution



Emergent fluxes



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