No breakdown of the radiatively-driven wind theory in low-metallicity environments

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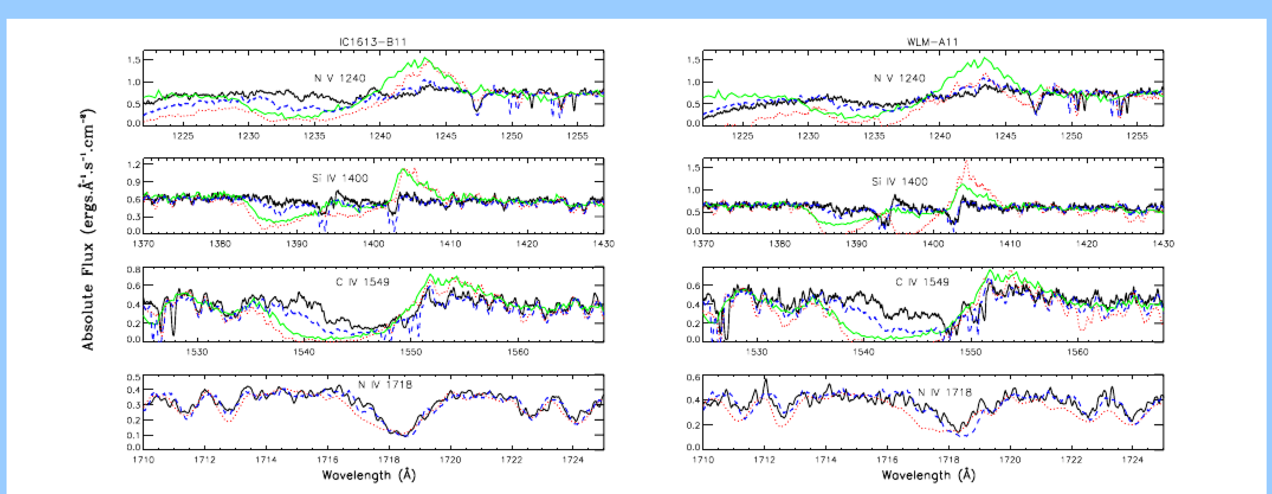
Hot star winds are radiatively driven by the transfer of photospheric photons momentum to atmospheric material through absorption and scattering. The mass-loss rate of massive hot stars is thus dependent on the metal content. We present an analysis of the mass loss rate - metallicity relation, supported by observations made with HST/COS.

Introduction

Hot star winds are radiatively-driven by the transfer of photospheric photon momentum to the atmospheric material through absorption and scattering by spectral lines (Castor et al. 1975; Vink et al. 2001). The basic properties of stellar winds therefore depend on both the number of metal lines available to absorb photon momentum and on their ability to absorb (i.e., their optical thickness). CNO and intermediate elements are dominant line drivers for the outer supersonic part of the winds, while iron group elements are responsible for the inner, subsonic part where mass-loss rate is set.

Observations

We used the Cosmic Origins Spectrograph (COS) onboard the Hubble Space Telescope (HST), to obtain high-resolution (R ≈ 20,000) FUV spectra of the three brightest stars from Tramper et al. (2011), namely A13 and B11 in IC 1613 and A11 in WLM.
Our program GO 12867 was granted 18 orbits. Each target was observed in a sequence of 6 science exposures with COS using gratings G130M (λ1291, λ1327) and G160M (λ1577, λ1623). This sequence provides coverage without gap of the FUV spectrum between 1132 and 1798 A. Overlapping segments have been co-added to enhance the final signal-to-noise ratio. Thanks to the high efficiency of COS in the FUV and little extinction toward the host galaxies, we achieved typically SNR ≈ 25 per resolution element, in 6 HST orbits for each target (2 orbits for G130M and 4 orbits for G160M; the latest grating covers the C IV λλ1548, 1550 doublet and He II λ1640).

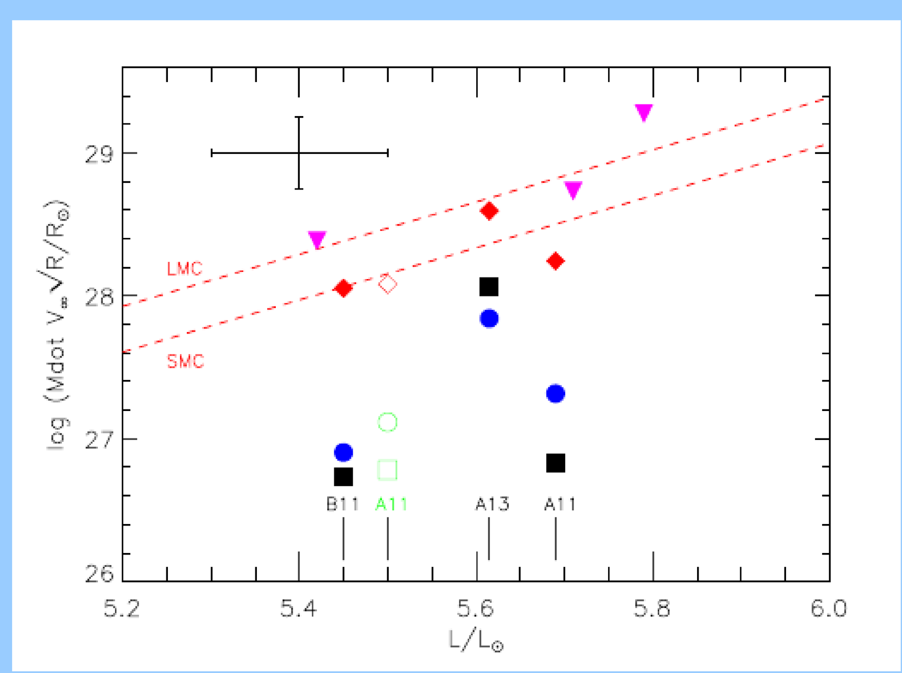


P Cygni profiles for two stars of our sample : B11 (left) and A11 (right) in black. Overplotted in red, green and blue are the spectra of the Galactic, LMC and SMC stars (respectively) chosen for comparison

Models and Methods

We compared the observed FUV + optical spectra of IC 1613-A13, IC 1613-B11 and WLM-A11 to synthetic spectra calculated with the NLTE stellar atmospheres code CMFGEN (Hillier & Miller 1998). CMF-GEN computes NLTE line-blanketed model atmospheres, solving the radiative transfer and statistical equilibrium equations in the comoving frame of the fluid in a spherically-symmetric outflow. The models we computed account for the presence of the following species: H, He, C, N, O, Ne, Mg, Si, P, S, Cl, Ar, Ca, Fe, Ni, representing more than 7500 full levels (more than 2000 super-levels) and ≈ 135,000 lines. The density structure is described as an hyand ≈ 135,000 lines. The density structure is described as an hydrostatic part, in the quasi-static photospheric layers, smoothly connected to a β velocity law in the wind. The radiative acceleration is calculated from the solution of the level populations, and is used to compute a new inner structure (connected to the same β velocity law). The mass-loss rate, density, and velocity are related via the continuity equation. After convergence, a formal solution of the radiative transfer equation was computed in the observers frame, thus providing the synthetic spectrum for a comparison to observations.

Results



Modified wind-momentum luminosity relation for the sample stars. Black full squares mark D_{mom} calculated in this work. Blue full circles are D_{mom} calculated with the mass fluxes from Lucy (2012) for the stellar parameters, while red full diamonds are D_{mom} computed with the Vink et al. (2001) recipe. D_{mom} for WLM-A11 assuming log L/L = 5.5 are indicated as empty symbols (same shape and color coding as previously). The dashed red lines are the theoretical relation for LMC and SMC metallicities predicted by Vink et al. (2000). Pink triangles are D_{mom} from Tramper et al. (2014) for the three stars.

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