The evolution of massive stars and their spectra I. A non-rotating 60 Msun star from the zero-age main sequence to the pre-supernova stage

Jose Groh (1), Georges Meynet (1), Sylvia Ekstrom (1), Cyril Georgy (2)

(1) Geneva Observatory, Switzerland
(2) Keele University, UK

For the first time, the interior and spectroscopic evolution of a massive star is analyzed from the zero-age main sequence (ZAMS) to the pre-supernova (SN) stage. For this purpose, we combined stellar evolution models using the Geneva code and atmospheric models using CMFGEN. With our approach, we were able to produce observables, such as a synthetic high-resolution spectrum and photometry, aiding the comparison between evolution models and observed data. Here we analyze the evolution of a non-rotating 60 Msun star and its spectrum throughout its lifetime. Interestingly, the star has a supergiant appearance (luminosity class I) even at the ZAMS. We find the following evolutionary sequence of spectral types: O3 I (at the ZAMS), O4 I (middle of the H-core burning phase), B supergiant (BSG), B hypergiant (BHG), hot luminous blue variable (LBV; end of H-core burning), cool LBV (H-shell burning through the beginning of the He-core burning phase), rapid evolution through late WN and early WN, early WC (middle of He-core burning), and WO (end of He-core burning until core collapse). We find the following spectroscopic phase lifetimes: 3.22e6 yr for the O-type, 0.34e5 yr (BSG), 0.79e5 yr (BHG), 2.35e5 yr (LBV), 1.05e5 yr (WN), 2.57e4 yr (WC), and 3.80e4 yr (WO). Compared to previous studies, we find a much longer (shorter) duration for the early WN (late WN) phase, as well as a long-lived LBV phase. We show that LBVs arise naturally in single-star evolution models at the end of the MS when the mass-loss rate increases as a consequence of crossing the bistability limit. We discuss the evolution of the spectra, magnitudes, colors, and ionizing flux across the star's lifetime, and the way they are related to the evolution of the interior. We find that the absolute magnitude of the star typically changes by ~6 mag in optical filters across the evolution, with the star becoming significantly fainter in optical filters at the end of the evolution, when it becomes a WO just a few 10e4 years before the SN explosion. We also discuss the origin of the different spectroscopic phases (i.e., O-type, LBV, WR) and how they are related to evolutionary phases (H-core burning, H-shell burning, He-core burning)

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Comments:

Email: jose.groh@unige.ch