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Properties of Massive Stars in the Tarantula Nebula
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Summary:

This thesis presents the quantitative analysis of massive O-type stars in the 30 Doradus region of the Large Magellanic Cloud. The data have been collected in the context of VLT-FLAMES Tarantula Survey (VFTS), an ESO Large Programme that has obtained multi-epoch optical spectroscopy of 800 OB-type stars using the Very Large Telescope (VLT) in Chile.

The first part of the thesis (Chapters 2 and 3) focusses on the stellar rotational properties of spectroscopic single and binary stars in 30 Doradus. The distribution of spin rates of massive stars is important because it is the fingerprint of their formation process, which it is not well understood, and an important ingredient for their evolution.

In the second part of the thesis, the focus shifts to properties of O-type giants, bright giants, and supergiants in the VFTS (Chapters 4 and 5). Using quantitative spectroscopy, we constrain the stellar and wind parameters, and the surface abundances of the objects in our sample. We then confront these observational constraints to the predictions of theories of the evolution of massive stars.

Rotational properties of massive stars in 30 Doradus

Here we investigate the rotational distribution of O-type stars in 30 Doradus. 30 Doradus is the nearest massive starburst and it contains the richest population of massive stars in the Local Group. Using multi-epoch optical spectroscopy of over 330 O-stars, VFTS identified 216 stars that are spectroscopically single (ΔRV <= 20 km/s) and 116 that are binary systems.

In Chapter 2 we investigate the rotational distribution of the presumed-single sample. We found that the distribution of rotational velocity shows a two-component structure: a low-velocity peak formed by 75% of the sample ($v_e \sin i$ < 200 km/s) and a high-velocity tail that contains the remainder of the stars. The presence of the low-velocity peak is consistent with previous surveys. Based on expectations of star formation and single-star evolution, most of the stars seem to have to spin down shortly after their formation, from critical or half-critical rotation rates to rotation speeds that are ~0.1-0.3 of break-up. For the bulk of the O stars, angular momentum loss in a stellar wind is insufficient to accomplish this and therefore another mechanism should act to efficiently spin down the stars; magnetic fields being a prime candidate. The presence of a well populated high-velocity tail is compatible with expectations from binary evolution, and qualitatively agrees with recent population synthesis calculations.

In Chapter 3 we investigate the rotational properties of stars in binary systems. We also found a low-velocity peak, though broader and slightly shifted to higher projected rotational velocities when compared to the spectroscopic single stars. We argue that our results are compatible with the assumption that binary components formed with the same spin distribution as single stars and that the different shape of the low-velocity peaks between single and binary stars is the result of *tidal interaction* affecting the spin of stars in close binary systems. Interestingly, the rotation distribution of binaries shows a lack of very rapidly rotating stars (i.e. stars with $v_e \sin i$ > 300 km/s). This finding is also in agreement with the hypothesis that the high-velocity tail in the presumed-single sample is populated by spun-up post-binary products.

Physical properties of the O-type giants, bright giants, and supergiants

In the second part of the thesis we investigate the stellar and wind properties, and the helium and

nitrogen surface abundances of the O-type giants, bright giants, and supergiants in the VFTS. In Chapter 4 we present the stellar properties of the giants to supergiants by using a genetic algorithm optimizing routine to fit synthetic line profiles generated by the non-LTE atmosphere code *fastwind* to the observed spectral lines. All of our stars are core hydrogen burning; most with stellar masses between 15-70 Msun, although a few objects are in the ~100 Msun range. We present temperature versus spectral sub-type calibrations as a function of luminosity class, which show an offset that concords with expectations. We investigate the possible correlation between helium abundance and (projected) rotational velocity and find that rotation induced mixing of gas in the stellar interior cannot explain all of our findings: the helium-enriched stars have $v_e \sin i$ < 200 km/s. Finally, we present the wind momentum versus luminosity diagram. Adopting theoretical results for the rate of acceleration of the wind flow, we find wind momenta for LMC stars that are 0.2 dex higher than earlier results.

In Chapter 5, we present the nitrogen abundances of the giants to supergiants. Having the stellar parameters, we devise a method to quickly and robustly determine the surface abundance of this element. The method compares the equivalent width of nitrogen lines with theoretical equivalent widths supplied by *fastwind* models. By comparing the nitrogen content of stars with their rotational velocity we confront the theory of rotational mixing in massive stars. With the typical signal to noise ratio of our data it is difficult to distinguish the nitrogen lines of rapid rotators (>=200 km/s) from the noise. The upper limits we retrieve for these objects do not contradict rotational mixing theory. For the slow rotators, however, we find a group of enriched stars that is not expected in the context of rotational mixing. We discuss possible explanations, which include binary evolution or the presence of a magnetic field.