Two Remarkable Spectroscopic Categories of Young O Stars from the VLT-FLAMES Tarantula Survey

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Abstract. The spectral and spatial characteristics of two special categories of O stars found in the VFTS dataset are presented. One of them comprises very rapid rotators, including several more extreme than any previously known. These objects are distributed around the peripheries of the main 30 Doradus clusters, suggesting a runaway nature for which their radial velocities already provide preliminary supporting evidence. The other category consists of a large number of Vz stars, previously hypothesized on spectroscopic grounds to be on or very near the ZAMS. Their distribution is the inverse of that of the rapid rotators: the Vz are strongly concentrated to the ionizing clusters, plus a newly recognized band of recent and current star formation to the north, which provides strong circumstantial evidence for their extreme youth.

1. Introduction

The VLT-FLAMES Tarantula Survey (VFTS; Evans et al. 2011) has produced an unprecedented spectroscopic dataset for the stellar content of the 30 Doradus Nebula in the Large Magellanic Cloud, the largest in the Local Group. About 800 OB stars have been observed with a resolving power of $\sim10^4$ at the Very Large Telescope of the European Southern Observatory (program 182.D-0222). It is reasonable to expect that such an advance over previous material will entail both observational and theoretical progress on the formation and evolution of massive stars. Indeed, some early, unexpected empirical developments, resulting from the spectral classification of 167 O stars
with no detected radial-velocity variations, are briefly described here; they will be amplified shortly by Walborn et al. (2012, in prep.), while the optimized classification atlas generated for this work will be presented by Sana et al. (2012, in prep.).

2. Rapid Rotators

In this subsample, 17 O main-sequence stars have very high projected rotational velocities in the range of 300–600 km s\(^{-1}\); the largest values previously known were just over 400 km s\(^{-1}\) (Howarth & Smith 2001; Walborn et al. 2011). An additional 7 rapid rotators have giant luminosity classes indicated, although the actual luminosities of such extreme objects may require further investigation. The spectra of 6 luminosity class V stars are displayed in Figure 1, labeled with their detailed spectral types and preliminary \(v\ \sin\ i\) measurements derived by SSD using a Fourier transform technique. (Definitive values will be derived by O. Ramírez-Agudelo et al. 2012 and C. Sabín-Sanjulián et al. 2012, in prep.). VFTS 285 is the current record holder. Remarkably, none of these spectra displays Balmer central stellar emission, even at H\(\alpha\), indicating a possible absence of disks. A related case probably with a disk is discussed by Dufton et al. (2011).

The spatial distribution of the main-sequence rapid rotators is shown in Figure 2. It is seen that all but 4 of them are located about the peripheries of the clusters NGC 2060 and 2070. This circumstance immediately suggests a possible runaway nature of the class. The VFTS radial velocities of these stars already provide supporting evidence for that interpretation, containing a high fraction of large values compared to the rest of the sample (Sana et al., these proceedings; et al. 2012, in prep.). A current Hubble Space Telescope imaging program by D. Lennon et al. may determine their proper motions, thus enabling a full kinematical analysis. We emphasize that a population of high-mass, extreme-rotator runaways from a massive young cluster is a new phenomenon, which may be related to theoretical dynamical predictions and to the origin of gamma-ray bursts (Dale & Davies 2006; Allison et al. 2010). A possibly related situation for the Galactic cluster Westerlund 2 has been presented by Roman-Lopes, Barbá, & Morrell (2011).

3. Zero-Age Main-Sequence Stars

A class of O-type spectra with empirical evidence of subluminosity is described by Walborn (2009). Briefly, they display He II \(\lambda\)4686 absorption stronger than any other He II or He I line. Since emission in that particular He II line is a progressive luminosity effect (the Of phenomenon), these spectra, assigned luminosity class Vz, have been hypothesized to represent the inverse effect, i.e. lower luminosity, higher gravity, and/or lower mass-loss rate than for normal class V. Although such spectra have systematically been found in young regions, we were surprised to encounter no fewer than 35 definite plus another 10 possible examples in the VFTS subsample discussed here. The spectra of a few of them are reproduced in Figure 3 (along with examples of some other special class V categories mentioned in the caption). The physical parameters of this category have not been investigated previously, but they will be in the extensive VFTS sample.

The distribution of the definite Vz objects is shown in Figure 4. It is essentially the inverse of the rapid rotator distribution, with a strong concentration toward the main clusters NGC 2060 and 2070. In addition, several of the Vz stars lie in an approxi-
Figure 1. Rectified spectral intensity plots of extremely rapid rotators. The VFTS catalogue numbers are followed by the spectral types and $v\sin i$ measurements. VFTS 190 has an Onfp spectrum with emission wings at He II $\lambda$4686 (Walborn et al. 2010a). The central Balmer emission is nebular; “SB?” signifies a relative displacement of the stellar absorption lines, although radial-velocity variations have not been detected in the available data.

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mately east-west band at the northern extreme of the field. The “isolated” WN stars R144, R146, and R147 (Feast, Thackeray, & Wesselink 1960) also lie in this band, as does one of the most luminous IR YSOs in the Spitzer images. Thus, this band evidently represents another, previously unrecognized region of recent and current star formation in 30 Dor, consistent with the presence of Vz stars there. This distribution
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Figure 2. Distribution of the rapid rotators (VFTS numbers in red), on a logarithmic MPG/ESO/WFI image of 30 Doradus; VFTS 751 and 755 are separated by 284″ in declination, or 71 pc in projection. North is up and east to the left. NGC 2060 is at the SW and NGC 2070 in the center. The unannotated red circles in the core are VFTS 465, 660, 654, and 706. The blue symbols correspond to O V((fc)) spectra (see Fig. 3 caption), which do not show any preferred locations.

provides strong circumstantial evidence for extreme youth of the Vz class, to be further investigated by quantitative analysis of the VFTS spectroscopic data.

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Figure 3. Rectified spectral intensity plots of Vz and some other subcategories of O-type main-sequence spectra, including V((fc)) with C III $\lambda$4650 emission lines comparable to N III $\lambda$4640 (Walborn et al. 2010b), He II wings stronger than He I (VFTS 638), and no N III or C III emission features whatever despite very high S/N (VFTS 849). Note that Vz spectra can be either ((f)) or ((fc)), or neither.

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Figure 4. Distribution of the Vz objects; image as in Fig. 2. The numerous stars in the central cluster will be identified by Walborn et al. (2012), where the complete spectral classifications will also be given.

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