A Massive Star Odyssey, from Main Sequence to Supernova
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Interaction between OB stars and the interstellar medium

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Abstract. From the emission line map in Hα over the full face of the spiral galaxy NGC 3359, we analyze the internal velocity structure of the H II region population. The emission line profiles show central peaks, with turbulent velocity widths of $\leq 20\,\mathrm{km\,s^{-1}}$, and also broad shallow wings, with typical velocities of $\sim 50\,\mathrm{km\,s^{-1}}$, with respect to the rest velocity of the H II region. We verify the identification of these wings as due to expanding gas, quantify the energy involved, and suggest physical models for their interpretation, as the effects of mechanical and radiative outflows from the central OB stellar cluster.

1. Introduction

We observed the barred SBc(rs) galaxy NGC 3359 in Hα emission with the TAURUS Fabry-Perot scanner on the 4.2m WHT (La Palma). The scan was in 55 steps, each of 0.34 Å interval, corresponding to a velocity step of $15.6\,\mathrm{km\,s^{-1}}$. For flux calibration we compared this map with the Hα catalogue for NGC 3359 from Rozas, Zurita & Beckman (2000). We selected a sample of isolated, circular-symmetric regions, covering the widest practical luminosity range. Within the catalogued radius of a region, we select different apertures and integrate the Hα flux for each individual plane. The line profiles for these apertures are decomposed into Gaussians, showing an intense central peak, plus two weaker Gaussians, essentially symmetrical in velocity with respect to the central wavelength.

Since TAURUS has non-gaussian wings in its PSF, these must be calibrated out to leave a reliable astronomical line profile. We have used the Lucy-method (Lucy 1974) — based on the statistical fluctuations of the frequency distribution within a spectrum — to prove that the observed wings are not instrumental artefacts. To quantify the wing profiles, we extracted the central intense gaussian emission component and subtracted off in quadrature the width of the central peak of the instrument PSF, and subsequently convolved this with the full instrument PSF. The result, after subtracting this from the observed profile, gives us a lower limit to the wing strength.

Table 1. Parameters for representative H II regions in galaxy NGC 3359.

region	R (pc)	$<v_{\rm shell}>$ ($\rm km\,s^{-1}$)	$n_{\rm shell}$ ($\rm cm^{-3}$)	$E_{\rm K}$ (10^{50} erg)	$E_{\rm wind}$ (10^{50} erg)	$E_{\rm turb}$ (10^{50} erg)	$E_{\rm rad}$ (10^{50} erg)
52	172.7	46.85	5.51	3.1	12.1	0.1	1636.6
51	185.7	47.20	6.77	3.8	12.3	0.2	1662.1
46	262.6	50.40	6.19	7.8	13.1	0.4	1778.9
45	255.4	46.45	7.92	4.3	13.3	0.4	1802.4
44	261.7	54.90	5.87	8.8	13.9	2.2	1883.0
33	204.8	44.90	6.40	10.6	18.5	0.9	2511.6

2. Analysis

The electron density of the shell $n_{\rm shell}$ is estimated from the ratio of the emission measure of the wings to that of the central peak. The kinetic energy of the expanding shell $E_{\rm K}$ is then obtained with the radius of the maxima aperture for which the wings are defined and a thickness of $\Delta R_{\rm reg} \approx 1$ pc (Chu & Kennicutt 1994). $E_{\rm wind}$ is obtained from the values of Leitherer (1998) for OB stars, and the turbulent energy $E_{\rm turb}$ with an ionized mass using the catalogued radius and an electron density of $1.5\,\rm cm^{-3}$. We suppose the ionized gas inside the H II region is moving with a velocity corresponding to the dispersion velocity of the central peak of the line profile. $v_{\rm shell}$ in Table 1 is a mean value between the velocity separation of the two wings with respect to the central velocity of the region.

A simplified model suggests that the wing components show the emission of an expanding shell structure moving inside the H II region. A further approach to the situation would explain the profiles in the context of a shell driven by mass-loaded winds from the central OB stars (Dyson, Williams & Redman 1995). The energy in the stellar winds is sufficient to cause the expansion of the observed shell. However, the stellar wind energy is only $\sim 1\,\%$ of the stellar radiative output $E_{\rm rad}$ — a lower limit assuming all ionizing photons at Lyman limit — (see Table 1). If this output were coupled to the surrounding gas with only $1\,\%$ efficiency, it would provide an effective power source for the observed shell. A mechanism for this coupling may well be offered by interstellar dust. Initial exploration of the dust-driven wind models using the principles explained in Elitzur & Ivezić (2001) looks promising. It is also interesting to speculate, that a fraction of the energy in the expanding shell is bled off and maintains the observed turbulence in the H II region.

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