DYNAMICAL EFFECTS OF STELLAR WINDS AND ASSOCIATED HII REGIONS ON THE INTERSTELLAR MEDIUM

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ABSTRACT. A dynamical model has been developed, describing the joint evolution of a stellar wind and an associated HII region during the main sequence life time of an OB-star. It is proposed that in case of spherical symmetry all dynamical features are obtained by dividing the flow into spatially homogenous regions separated by discontinuities (shock fronts, contact discontinuity and ionization front). Different phases in the dynamical evolution can be distinguished. The results show that the extension and structure of the HII region depends sensitively on the initial density of the ambient medium, the Lyman continuum photon rate and the mechanical wind power of the central star. This will be important for future high resolution observations.

1. INTRODUCTION

The state of the Interstellar Gas is strongly determined by energy input of early type stars in the form of a) radiation, b) stellar wind (SW) and c) supernovae (not discussed here). Already a decade ago Copernicus observations have shown that a SW exists for all stars of spectral type B5 and earlier [1]. On the other hand these stars also produce sizeable HII regions. Furthermore the conversion of the stellar energy output by a) and b) into *kinetic energy* of the Interstellar Gas is comparable for both processes [2]. Consequently, SW and HII regions are **associated** phenomena which must be adequately taken into account in a dynamical description. However, most elaborate theoretical models so far have been dealing either with pure photoionized HII regions or SW bubbles alone, each subject to a variety of different boundary conditions. The objective of this work has been to analyze how basic physical processes modify the combined dynamics.

2. MODEL

Consider a single star of spectral type OB, emitting an isotropic steady wind and Lyman continuum photon flux into a homogenous and extended surrounding medium. The flow is then described in spherical geometry, "switching on" the SW and radiation field simultaneously.

It turns out that the flow can be divided into spatially homogenous regions (fig. 1) connected by conservation of mass, momentum and energy across the discontinuities (details s. [3]). In region (1), SW gas is moving with uniform velocity V_w, most of its kinetic energy being transformed into heat thus leading to an **isobaric** and **adiabatic** hot "bubble" (region (2)). It is in pressure equilibrium with the dense, thin and **isothermal** shell of shocked HII region (region (3)). When the unshocked HII region (region (4)) expands gasdynamically it creates a strong shock giving rise to a dense shell

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of neutral gas (region (5)). We start numerical integration using similarity solutions for the SW [4][5] and follow the time-dependent evolution of the dynamical variables.

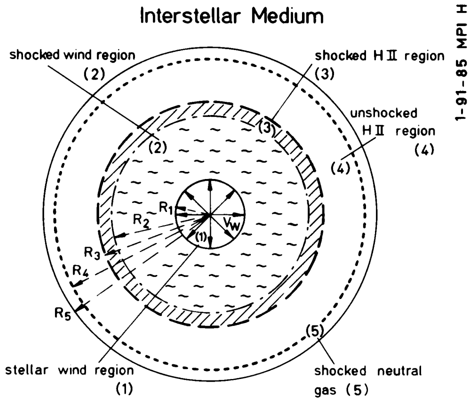

Figure 1. Model for the gas flow in the vicinity of a central OB-star; the various regions and their outer boundaries are: unshocked SW (1) and terminal shock (R_1), shocked SW (2) and contact discontinuity(R_2), shocked HII region (3) and outer wind shock (R_3), unshocked HII region (4) and ionization front (IF) (R_4), shocked HI gas (5) and IF-precursor shock (R_5).

3. RESULTS AND DISCUSSION

Model calculations have been performed for an O9 star (mass loss rate $\dot{M}_w = 10^{-7} M_\odot/\text{yr}$, wind velocity $V_w = 2000\text{km/s}$ and Lyc photon rate $S_* = 2.1 \cdot 10^{48}\text{s}^{-1}$) in media with number densities 10 and 10^4cm^{-3}. Three phases of time evolution can be distinguished. In the early phase the ionization front(IF) and SW regions evolve independently (very unlikekly to observe). In the intermediate phase they are coupled by the gasdynamical expansion of the unshocked HII region and the shock (R_2) behind the IF can catch up with it (interactions). The late phase strongly depends on the ambient density. For low densities (10cm^{-3}) the evolution of the HII region is determined by its gasdynamical expansion leading to extended HII regions whereas for high densities (10^4cm^{-3}) the SW dominates the dynamics and large bubbles with "skinlike" HII regions form. The "thickness" and the dimensions of the HII region are also strongly correlated with the ratio of wind power ($L_W = (1/2)\dot{M}_w V_w^2$) to photon rate. For high values of L_W/S_* we get thin ionized regions and huge bubbles and for low values rather thick and extended HII regions. The model is able to reproduce these time-dependent results quantitatively for given initial parameters of the star and its ambient medium. It is strongly suggested that VLA observations should be carried out in the future to reveal the detailed structure predicted here. Finally, the dimensions and dynamics of supernova remnants would also be affected by that.

References.

[1] Snow, T.P. and Morton, D.C., 1976 *Ap. J. Suppl.* **32,** 429
[2] Dyson, J.E., 1981 *Investigating the Universe,* F.D. Kahn (ed.), D. Reidel Publ, Comp.
[3] Breitschwerdt, D., 1985 *Dissertation,* Univ. Heidelberg
[4] Dyson, J.E. and deVries, J., 1972 *Astr. Astrophys.* **20,** 223
[5] Weaver, R., McCray, R., Castor, J., Shapiro, P., Moore, R., 1977 *Ap. J.* **218,** 377