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THE DYNAMICS OF STELLAR WINDS: THEIR STRUCTURES AND [OIII] LINE FORMATION

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ABSTRACT

To understand the dynamical structures of stellar wind bubble, one and two-dimensional calculations has been performed. Using FCT Code with cooling effects and assuming constant mass loss rate and ambient medium density, we could divide stellar winds into the regime of slow and fast winds. The slow wind driven bubble shows initially radiative and becomes partially radiative bubble in which shocked stellar wind zone is still adiabatic. In contrast, the fast wind driven bubble shows initially fully adiabatic and becomes adiabatic bubbles with radiative outer shell. We also determine analytically the onset of thin-shell formation time in case of fast wind driven bubble with power-law energy injection and ambient density structure. We solve the line transfer problem with numerical results in order to calculate line profile of [OIII] forbidden line.

Key Words : slow and fast wind, thin-shell formation time, [OIII] line

I. INTRODUCTION

Most of stars and some astronomical objects have an energy release phenomenon in their life (Mathews, 1966; Smith, 1973; Shcheglov, 1969; Meaburn, 1970, 1971; Zuckerman, 1977; Lada, 1985; Van der Hucht, 1992;). The blown out material and energy make the four basic structures in stellar wind bubble: unshocked stellar wind, shocked stellar wind, shocked ambient medium and unshocked ambient medium region (Pikel'ner and Scheglov, 1969). Each region is divided with discontinuities such as stellar wind shock, contact discontinuity and ambient shock. We have performed one and two-dimensional calculations. The basic physical quantities are examined in detail by numerical calculation. In the numerical calculations, we assume homogeneous ambient medium and include cooling effect. Slow and fast wind regime can be treated by their injection velocity and mechanical luminosity (Koo and McKee, 1992a,b) of $v_{cr} = 286\,(L_{38}n_o)^{\frac{1}{11}}\ km/sec$. We have set the two initial conditions for calculation: smaller velocity than v_{cr} (slow wind) and larger one (fast wind). We also calculate the thin-shell formation time in fast wind case by the analytical method of Franco et al(1994) and [OIII] line formation.

II. RESULTS

(a) The Dynamics of Stellar Winds

Slow wind experiences three evolution stages. radiative bubble, partially radiative bubble and pressure confined bubble (Koo and McKee, 1992a). The large amount of radiation cooling has been occurred in radiative stage, forming a thin, compressed outer shell(Fig. 1). The numerical result describes it very well. In partially radiative bubble stage, there is very small cooling in shocked stellar wind region, enlarged more and more. We stopped the calculation partially radiative bubble stage, not continued to pressure confined bubble stage because of time limit.

Fast wind makes fully adiabatic bubble initially, and adiabatic bubble with radiative outer shell in later(Fig. 2). The transition time is called "thin-shell formation time". The time from numerical calculation has been obtained about 5000 ~ 7500 *yrs*, and the analytical calculation gives 5200 *yrs*. The small discrepancy between them is accused by the cooling curve.

The pressure pulse is generated when cooling becomes effective and propagates toward the inner part of bubble. This is occured in narrow region near contact discontinuity. If there is cooling effect continued, the secondary shock is generated continuously. In the shocked ambient medium, eventually a thin shocked region should be produced.

In Two-dimensional calculation, we can see the major parts of stellar wind bubbles. The physical quantities are well coincided with one-dimensional calculations.

(b) Energy Budget and [OIII] Line

The evolutionally changes of radiative, kinetic and thermal energies are carefully examined. There is a little inconsistency in kinetic and thermal energies compared to analytic solution of Koo and McKee(1992a) which was assumed to be self-similar state. The discrepancy can be explained with the difference of cooling curves (Choe, Koo and Cha, 1996). The radiative energy, however has been good agreed.

The overall feature of calculated [OIII] line has double peaks with wide wing. For small impact parameter "b", the radiative outer shell of fast wind bubble makes double peaked line profile that corresponds approaching and receding shocked regions at large velocity. Central peak line profile is produces when the line of sight penetrates through edges of the radiative outer shell.

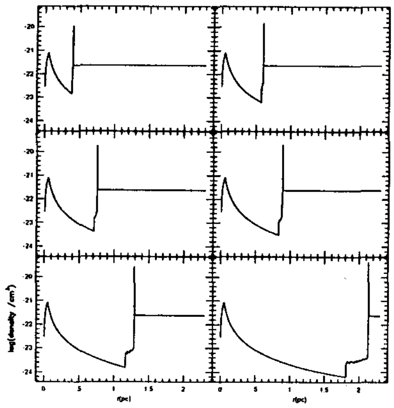

Fig. 1.— The density profile of slow wind. Time steps are $0.5, 1, 1.5, 2, 4, 10(\times 10^4)yrs$.

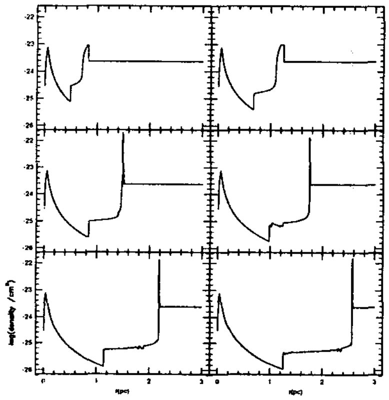

Fig. 2.— The density profile of fast wind. Time steps are $0.25, 0.5, 0.75, 1, 1.5, 2(\times 10^4)yrs$.

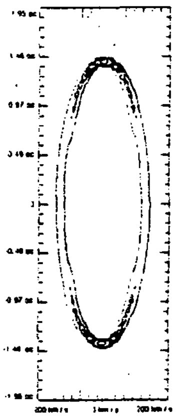

Fig. 3.— The position-velocity map of [OIII] line in fast wind bubble.

It shows a good agreement with an observation of expanding shell structure(Fig. 3).

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