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FORMATION OF LINE PROFILES BY THE WINDS OF EARLY TYPE STARS

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ABSTRACT

We have solved the radiative transfer problem using a Sobolev approximation with an escape probability method in case of the supersonic expansion of a stellar envelope to an ambient medium. The radiation from the expanding envelope turns out to produce a P-Cygni type profile. In order to investigate the morphology of the theoretical P-Cygni type profile, we have treated V_{∞}, V_{sto}, β (parameter for the velocity field), $\dot{M}$ and ϵ (parameter for collisional effect) as model parametrs. We have found that the velocity field and the mass loss rate affect the shapes of the P-Cygni type profiles most effectively. The secondarily important factors are V_{∞}, V_{sto} . The collisional effect tends to make the total flux increase but not so much in magnitude. We have infered some physical parameters of 68 Cyg, HD24912, and ξ persei such as V_{∞}, $\dot{M}$ from the model calculation, which shows a good agreement with the observational results.

Key Words : P-Cygni line profile, radiative transfer, Sobolev approximation, escape probability, velocity field, mass loss rate

I. INTRODUCTION

It is important to analyze the obsevational emission line and absorption line in the star and interstellar medium system. The P-Cygni type profile is observed in the single star system with expanding atmosphere. The P-Cygni type profile is variable and depends on the physical condition in the system. Castor(1970) has obtained expressions for the emergent line profile for a radially expanding envelope. He has used escape probabilities to calculate the line source function. If the envelopes are not optically thin, it is necessary to solve the formidable line transfer equation in a moving medium. Sobolev has developed a method for solving such problems based on neglecting the intrinsic line width relative to the Doppler displacement. With this method Sobolev has defined photon escape probabilities which can be used in the equations of statistical equilibrium of the atomic level populations. In case that the stellar envelope is not a spherical symmetry, the radiative transfer can be solved by a generalized Sobolev method which has been developed by Rybicki and Hummer(1978). This method can be applied to the three-dimensional flows with non-local radiative coupling. Hempe(1982) and Baade(1986) developed the computer code for solving the non-spherical, multi dimensional radiative transfer problem.

We have used the Sobolev approximation as a basic theoretical method and have used the computer code developed by Baade(1993). We have adapted that code to single star system. The purpose of this study is to investigate the formation and variation of the line profile theoretically through the model calculation. We have solved the radiative transfer equation in the SEI(Sobolev with Exact Integration) method. We have calculated the line profiles with changing the condition of the system, e.g., final velocity(V_{∞}), stochastic velocity(V_{sto}), velocity distribution in the velocity field(β), the mass-loss rate of the star($\dot{M}$), the ratio of collisional to total de-excitation rates from the upper level (ϵ), and so on.

II. MODEL CALCULATION

It is the intensity of emergent radiation flux that we want to get which forms the line profiles, changed in the various frequencies. It is calculated through the integration of the radiative transfer equation. In the star-centered coordinate, the intensity is calculated by setting the net-point-structures in the integrating range for the frequency, distance from the star, and azimuth on the celestial sphere. Whenever the calculation is accomplished in each net-point, the source function is interpolated.

To calculate the P-Cygni type line profile in the expanding envelope of the stars which have strong stellar winds, the model parameters have been adapted for the two models. To envestigate the change of line profile for each parameters, the various parameters have been adopted like that V_{∞}, V_{sto}, β, $\dot{M}$, ϵ in the reasonable range.

III. RESULT

It is velocity field that affects the shape of the line profile sensitively. The result of the small ϵ has no difference with that of the pure scattering ($\epsilon = 0$). So, the collisional effect need not to be considered.

The observations can be compared with the results using the theoretical model calculation. Three objects are adopted, showing P-Cygni type C IV line profiles in UV region. 68 Cyg is a ordinary O 7.5III type star(Howard and Smith, 1995). The observation estimates the velocity, $V_{max} = 2930\mathrm{kms}^{-1}$. This value is similar to the value of our model calculation of $V_{\infty} = 3000\mathrm{kms}^{-1}$ (Fig.1). Prinzja and Balow(1990)

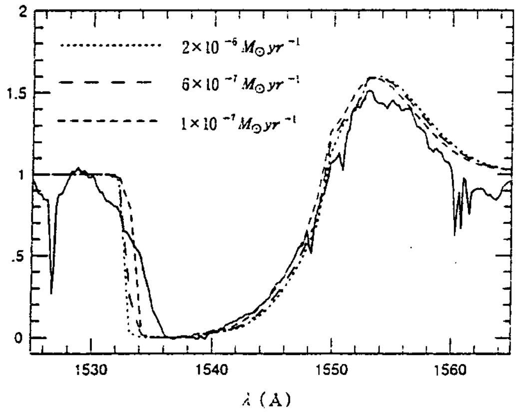

Fig. 1.— The observed and calculated CIV (λ=1550.8 Å) lines of 68 Cyg. Model calculation estimates the physical values of 68 Cyg star; V_∞ = 3000 km s^{-1}, V_{sto} = 200 km s^{-1}, $\dot{M} = 1 \times 10^{-7} \sim 2 \times 10^{-6}$ M$_\odot$yr^{-1}

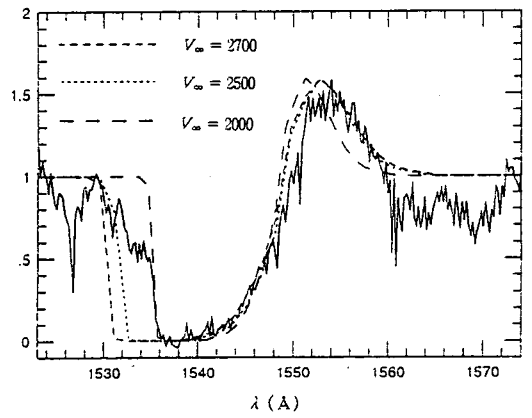

Fig. 2.— The observed and calculated CIV (λ=1548.2 Å) lines of HD24912. Model calculation estimates the physical values of HD24912; V_∞ = 2500 ~ 2700 km s^{-1}, $\dot{M} = 1 \times 10^{-6}$ M$_\odot$yr^{-1}

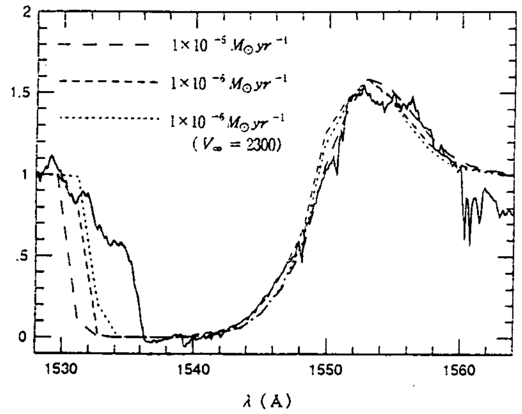

Fig. 3.— The observed and calculated CIV (λ=1548.2 Å) lines of Ξ Persei. Model calculation estimates the physical values of Ξ Persei; V_∞ = 2500 km s^{-1}, $\dot{M} = 1 \times 10^{-6} \sim 1 \times 10^{-5}$ M$_\odot$yr^{-1}

estimated the stellar wind velocity of HD24912, OIII type star; V_{max} = 2500kms^{-1} , V_∞ = 2330kms^{-1} . We estimate the physical values of V_∞ = 2500kms^{-1} , V_{sto} = 300kms^{-1} , and $\dot{M} = 10^{-6} M_\odot yr^{-1}$ (Fig.2). ξ Persei, O 7.5 giant star has the P-Cyg profile of CIV line(Henrichs et al., 1994). We estimate V_∞ = 2500kms^{-1} and $\dot{M} = 10^{-6} \sim 10^{-5} M_\odot yr^{-1}$ (Fig.3).

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