MASS LOSS FROM α ORI

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High dispersion spectrograms of α Ori are obtained. Several strong absorption lines which have circumstellar components are measured. Assuming the plane-parallel envelope and thermal equilibrium, the mass loss rate is estimated as 1×10^{-6} $M_{\odot}$/yr.

1. Introduction

To obtain the mass loss rate of red giant stars is very important in connection with the study of the stellar evolution. Several authors have observed circumstellar lines and obtained mass loss rate using precise theories of radiation transfer. However, accuracy of the studies seems to depend not on the adopted theories but on the dispersion of spectrograms, since the structure of the circumstellar space is too complicated to be expressed by,e.g.,single expansion velocity. Because our spectrograms have higher dispersion, compared with others, our study is meaningful, though the assumed model is very simple.

2. Observations

Two types of spectrograms were used to determine the mass loss rate of α Ori. One was made by the 65 cm solar coudé telescope at Okayama Observatory, using an image intensifier, in January, 1979. The observed lines are BaII 4554, KI 7699, NaI D 5896. The dispersion is about 0.6 A/mm. Another was made by the 188 cm telescope with Échelle spectrometer at Okayama Ovservatory, in January, 1972. The lines of SrII 4078, CaI 4227, CrI 4254, 4274, 4290 were measured. The dispersion is about 1.4 A/mm. Every line of both spectrograms which exhibit strong circumstellar components is resonance line.

3. Model of Circumstellar Envelope

The radiation whish has symmetric line profile of the photosphere passes through the expanding circumstellar envelope, where the absorption and emission of an element make the line asymmetric. An example of a line shape is shown in Fig.1.

C. Chiosi and R. Stalio (eds.), Effects of Mass Loss on Stellar Evolution, 113–115.

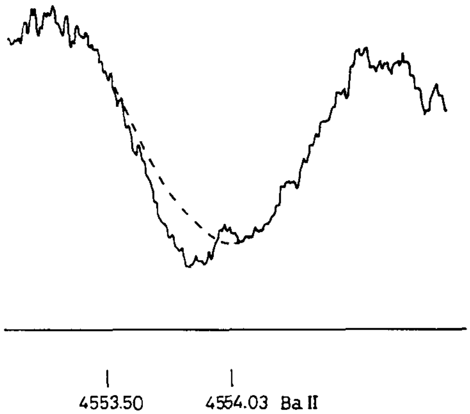

Fig.1 Intensity tracing of BaII line

The model of the circumstellar envelope is made from next assumptions 1) The envelope is plane-parallel. The emission component which has minor contribution is ignored. 2) The expansion velocity is constant. 3) The particle density, n, is proportional to r^{-2}. Thus the intensity of the radiation is expressed by the following equation.

$$dI(\nu)=-\alpha(\nu)I(\nu)n\,dr \tag{1}$$

where absorption cross-section $\alpha(\nu)$ is

$$\alpha(\nu)=\frac{\sqrt{\pi}e^2 f}{m_e\nu_0 V}\exp\left\{-\left(\frac{c}{V}\frac{\nu-\nu_0}{\nu_0}-\frac{V_e}{V}\right)\right\}^2 \tag{2}$$

with

$$V^2=\frac{2kT}{M}+V_t^2 \tag{3}$$

V_e : expansion velocity
V_t : turbulent velocity

and the other notations have usual meanings. In the region in question, the inequality $2kT/M \ll V_t^2$ holds. Therefore we can get

$$I(\nu)=I_1(\nu)\exp(-\int n\,dr\,\alpha(\nu))$$
$$=I_1(\nu)\exp(-N\alpha(\nu)) \tag{4}$$

where $I_1(\nu)$ is the intensity of photospheric line and N is the column density. $\alpha(\nu)$ is calculated from eqation (2), if V_e and V_t are to be parameters. Comparing the calculated $\alpha(\nu)$ with the observed profile, we can determine V_e, V_t and the column density of an element.

4. Ionization Rate

To get the column density of total elements, it is necessary to calculate the ionization rate. Several assumptions are required for this calculation. 1) Thermal equilibrium holds within the envelope, that is, Saha's equation can be used. 2) The ionization rate is independent of the distance from the star. 3) The chemical composition within the envelope is same as the cosmic or solar abundance, which enables us to compute the column density of total elements. From these assumptions, the ionization rate is determined in the following scheme. First, we assume

$$\frac{N(BaI)}{N(NaI)}=\frac{n(BaI)}{n(NaI)}=\left[\frac{n(BaI)}{n(NaI)}\right]_{\text{cosmic abundance}} . \tag{5}$$

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N(NaI) is obtained from the observed line and N(BaI) is calculated from equation (5). Second, from the ratio of N(BaII) to N(BaI), we can calculate electron density,n_e, when ionization temperature,T,is dealt with as a parameter. Third, with this determined n_e, we can calculate the electron density from electron donners such as Al, Ca, Na,.... If both electron densities are not equal, T is replaced by T+ΔT and we repeat the same calculation. When n_e and T are determined, the ionization rate is given by the diluted Saha's equation. Following scheme is straightforword and the column density of hydrogen are computed.

5. Results and Discussions

Mass loss rate is calculated in the following equation.

$$-\frac{dM}{dt} = 4\pi r\ N_H m_H V_e$$

We assume r is 10 R_*, which is used also in the preceding section. The calculated values and other parameters are listed in Tab.1.

Tab. 1 Determined mass loss rates and other parameters

	V_t (km)	V_e (km)	N (cm^{-2})	N_H (cm^{-2})	$-\frac{dM}{dt}$ ($M_\odot$/yr)
BaII 4554	9.0	14.5	5.4(11)*	3.6(21)	1.1(-6)
KI 7699	2.0	5.2	8.0(10)	1.6(23)	1.7(-5)
NaI 5896	6.5	11.0	2.5(12)	5.4(21)	1.3(-6)
SrII 4078	7.0	10.0	1.4(12)	1.7(21)	3.6(-7)
CaI 4227	9.0	12.5	1.2(12)	1.3(19)	3.3(-9)
CrI 4254	7.5	11.3	1.6(12)	6.9(18)	1.6(-9)
CrI 4274	5.0	11.0	2.1(12)	9.0(18)	2.1(-9)
CrI 4290	6.0	10.5	3.0(12)	1.3(19)	2.9(-9)

(*5.4(11)=5.4×10^{11}) T=2000K , $n_e=3.0\times10^2$ (r=10 R_*)

The ionization temperature 2000K is related to the UV radiation of α Ori. Though we have not made an exact calculation of the intensity of the UV radiation from α Ori, its value seems to be reasonable.

The effect of the emission component to the mass loss rate is estimated as 10%, therefore it has little influence on the results.

The mass loss rates obtained from CaI and CrI lines are too small. We cannot exactly explain this fact but one suggestion is probable that Ca and Cr are solidified in the dust within the envelope; Morton,D.C. (1974) studied the interstellar gas toword ζ Oph and it is shown that Ca and Cr are most depleted.

In conclusion, the mass loss rate of α Ori is estimated as 1×10^{-6} $M_\odot$/yr.

Reference

Morton,D.C. 1974, Ap.J.,193,L35.