CONSISTENT SPHERICAL NLTE-MODELS FOR BN-LIKE OBJECTS

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ABSTRACT. Spherical NLTE-model photospheres surrounded by envelopes are calculated in order to interpret BN-like objects. Both the existence and the emitted spectra of the HII-region can be understood by such models.

1. INTRODUCTION

In recent years a number of objects similar to the Becklin-Neugebauer-object (BN) in Orion have been found. These are thought to be hot protostars or young stars which are surrounded by compact high density HII-regions and neutral dust shells. The luminosities are those of main sequence B stars (Wynn-Williams, 1982).

2. THE MODEL CONSTRUCTION

The models can be characterised by the following:

i) Spherical geometry with a run of density that is given by a power law r^{-n} or by the hydrostatic equation in the photosphere of an underlaying main sequence B star. All parts of the configuration (e.g. the radiation field and the run of temperature in the photosphere and envelope) are calculated consistently.

ii) For hydrogen eight levels are allowed to deviate from LTE. All transitions are included both in the statistical equation and radiative transfer. Since it is not clear which parts of the observed velocity fields are due to outflow, rotation or turbulence, we mimic the velocity by a (micro-)turbulent velocity.

iii) Continuous opacities are taken into account for the whole wavelength range from the EUV to the cm region.

iv) Radiative equilibrium is assumed for the whole object.

3. COMPARISON WITH OBSERVATIONS

The observational indicators for the free parameters are shown in table II. If suitable observations are not available, we took v_{turb} =100 km/s as a standard value.

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TABLE I. Parameters which are not changed in almost all calculations

Model parameter	assumptions
Luminosity class	V
Density distribution	r^{-2}
Condition for the outer radii	ionisation bounded
$v_{turb}(r)$	constant
Chemical composition	solar

TABLE II. Free model parameters and their indicators

Model parameter	Indicator
Effective temperature T_{eff}	Integrated continuum fluxes and distances; Linie ratios
Footpoint density N_o	Flux of Brα
v_{turb}	Mean half widths of lines
Extinction A_V	Ratio $F_{Br\gamma}/F_{Br\alpha}$

TABLE III. Models of BN-like objects. The effective temperature T_{eff}, the stellar radius r_*, the footpoint density N_o at the inner boundary of the nebulae, the turbulent velocity v_{turb}, the calculated radius of the HII-region r_{HII}, the extinction A_V as determined by the line ratio of $F_{Br\alpha}/F_{Br\gamma}$ and the mass loss rate $\dot{M}$ (indicated by the models if the observed line widths are entirely due to an outflow) are given.

Object	T_{eff} [K]	r_* [$R_\odot$]	N_o [cm^{-3}]	v_{turb} [km/s]	r_{HII} [AU]	A_V [mag]	$\dot{M}$ [$M_\odot$/year]	Remarks
S106 IRS4	28000.	5.2	1.10^{12}	100.	15.0	16.8	$5\cdot10^{-7}$	
BN	28000.	5.2	3.10^{12}	20.	6.7	25.6	$3\cdot10^{-7}$	
M17-IRS1	25400.	4.3	1.10^{13}	100.	2.5	20.7	$5\cdot10^{-6}$	
S140-IRS1	25400.	4.3	1.10^{13}	100.	-	-	-	outer radius is 43 $R_\odot$ and $N(r)\sim r^{-3}$
CRL961	22400.	4.1	1.10^{13}	100.	1.7	29.8	$4\cdot10^{-6}$	
MonR2-IRS3	22400.	4.1	5.10^{12}	100.	-	>42	$2\cdot10^{-6}$	model of CRL961 but scaled N_o
CLR490	17500.	3.8	1.10^{12}	130.	0.8	12.6	$6\cdot10^{-7}$	

The given fluxes (see Table IV) are extinction corrected by the van de Hulst curve No. 15. They are normalized to r_*. For the given mass loss, we assume that all parts of the observed velocity fields are connected to an outflow. Therefore $\dot{M}$ should be regarded as an upper limit.

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TABLE IV. Comparison of predicted with observed fluxes (see Hall et al., 1978; Thompson und Tokunaga, 1979; Simon et al., 1981; Simon et al., 1983), corrected for extinction (in brackets).

Objects	S106-IRS4	BN	M17-IRS1	S140-IRS1	CLR961	CLR490
$\lg(F_{Br\alpha})$	8.60(8.7)	8.77(8.7)	9.54(9.6)	7.53(7.6)	9.44(9.5)	8.54(8.6)
$F_{Br\alpha}/F_{Br\beta}$	1.75(-)	1.86(-)	1.18(-)	0.45(-)	1.20(-)	1.75(-)
$F_{Br\alpha}/F_{Br\gamma}$	2.24(2.3)	2.40(2.4)	1.26(1.3)	0.23(-)	1.38(1.4)	1.90(1.9)
$F_{Br\alpha}/F_{Pf}$	6.17(-)	5.24(-)	4.85(-)	2.18(-)	5.50(-)	4.80(-)
$F_{Br\alpha}/F_{Pf}$	7.08(6.7)	4.50(4.6)	3.55(3.7)	1.09(1.0)	4.25(4.2)	4.30(2-3)
$v_{HW\ Br\alpha}$(km/s)	110(110)	28.(30)	140.(-)	120.(-)	125.(-)	145.(-)
$v_{HW\ Br\gamma}$(km/s)	95.(110)	27.(30)	130.(135)	120.(-)	125.(-)	145.(150)
$\lg(F_{1.3cm})+12$	8.0(8.1)	7.9(-)	7.25(<8.7)	-	6.7(<8.)	6.0 (8.2)
$\lg(F_{6.0cm})+12$	7.2(7.6)	6.8(<7.2)	5.92(9.1)	-	5.3(-)	4.7(<7.7)

4. CONCLUSION

i) The existence of ionised envelopes around B stars can be understood by such models. The main mechanisms are ionisation by Balmer continuum photons, strong bound-bound collisions, small radiative net rates, and small dilution factors in contrast to classical HII-regions.

ii) There is a complicated interplay between densities, temperatures and occupation numbers. The occupation numbers for higher levels (main quantum number greater than 6) are almost completely determined by the collisional rates.

iii) The backwarming of the outer photospheric layers caused by the envelope may amount to several thousand degrees.

iv) The lines of BN-like objects can be fitted by models which in most cases have a run of density $\sim r^{-2}$. The line profiles can be explained by turbulence of the order of 100 km/s and by Stark broadening.

v) The models are compatible with the radio observations.

vi) For several BN-like objects for which suitable observational data are available, reliable luminosities can be determined from the models.

vii) The intrinsic reddening was determined.

For more detailed information see (Höflich,1986; Höflich, Hartmann and Wehrse, 1986).

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