MODELS FOR THE EMISSION-LINE SPECTRA OF THE LOW-EXCITATION HERBIG-HARO OBJECTS

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Abstract

The class of Low-Excitation Herbig-Haro Objects are characterised by [SII] and [OI] lines which are comparable in strength to H-Alpha, by [NI] lines that are comparable to H-Beta, relatively weak [NII] and [OII] lines, little or no [OIII] emission and a very strong blue-UV "excess".This blue and UV continuum in low-excitation HH Objects was noted as a problem by Brugel, Böhm and Mannery (1981) , Ortalani and D'Odorico (1980) and Böhm, Böhm-Vitense and Brugel (1981). The first suggestion that it results from collisionally enhanced Hydrogen two-photon (2q) continuum was by Dopita (1981). The subsequent observations of Dopita, Binette and Schwartz (1982) proved that this was indeed the case. However, although very close correlations between this enhancement and the emission-line spectrum were found, a fair theoretical description could only be obtained for very youthful shock models with ages of order 30 years. However, there seems to be no reason why low excitation HH shocks should be much younger than the high excitation shocks.

It is clear that a collisional excitation of atomic hydrogen is a dominant mechanism. The régime in which the early models and the observations diverge is precisely at velocities for which the material entering the shock is no longer appreciably pre-ionised. A prerequisite to obtain a large 2q enhancement is the existence of a zone with a substantial un-ionised fraction of Hydrogen. Ohtani (1980) has emphasised that the relaxation between electrons and ions could become important in low velocity (non-preionising) shocks. Indeed this process is important wherever the cooling of the electron gas by inelastic collisions becomes comparable with the energy gain through superelastic collisions, such as is the case in shock models for oxygen-rich gas (Itoh, 1981a,b; Dopita, Binette and Tuohy, 1984). In this case a zone with different ion and electron temperatures can be maintained provided that there is no collective heating of the electrons (McKee 1974 ;Pravdo and Smith 1979).

Using our code MAPPINGS, we computed a set of models with no collective heating for a variety of shock velocities. Gas in the pre-shock zone is initially in ionisation and temperature equilibrium with starlight at 8000K with a dilution factor of 10^{-12}. The composition is solar, except for the refractory elements Mg and Si, which had to be depleted, presumably the result of trapping on grains. The 'Best Fit' chemical composition is, by number: H:He:C:N:O:Ne:Mg:Si:S =

1 : 0.1 : 4.2E-4 : 8.7E-5 : 6.9E-4 : 9.8E-5 : 2.8E-6 : 2.7E-6 : 1.9E-5.

The effect of electron-ion relaxation is to prevent the electron temperature rising above the point at which collisional ionisation losses are becoming important. The individual line flux ratios given in Table 1 are generally in very good agreement. The [NI]/[NII] is rather too high, which suggests that the charge exchange reaction rate may still wrong. The spectrum of HH43 includes the higher excitation knot HH43A.

TABLE 1: A COMPARISON OF A MODEL (v_s =45km/s) WITH LOW-EXITATION H-H OBJECTS.

Ion	Wavelength	Shock Model	HH43A-C	HH47
CII]	2326	124	258	—
[OII]	2470	2.5	34	—
MgII	2800	36	82	—
CI]	2968	163	77	—
[OII]	3727/29	156	113	87
[SII]	4068/76	43.6	68.5	81
HI	4101	20.0	16.1	20.4
HI	4340	40.4	40.6	43.7
MgI]	4562/71	40.9	15.2	39.0
Hß	4861	100	100	100
[OIII]	4959	0.0	2.1	—
[OIII]	5007	0.0	6.4	—
[NI]	5198/200	171	111	127
[OI]	6300	374	340	320
[OI]	6363	123	110	101
[NII]	6548	4.9	30	26
HI	6563	405	437	463
[NII]	6584	14.5	90.1	67
[SII]	6717	521	343	448
[SII]	6731	475	326	471
F(2q)/F(Hß)		97.9	123	145

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