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Conference or Workshop Item

How to cite:

Saraceno, P.; Benedettini, M.; Caux, E.; Ceccarelli, M. C.; Clegg, P. E.; Correia, J. C.; di Giorgio, A. M.; Giannini, T.; Griffin, M. J.; Leeks, S. J.; Liseau, R.; Lorenzetti, D.; Molinari, S.; Nisini, B.; Smith, H.; Spinoglio, L.; Tomassi, E. and White, G. J. (1997). Molecular line emissions from pre main sequence objects. In: The first ISO workshop on Analytical Spectroscopy, 6-8 Oct 1997, Madrid, Spain, p. 291.

Version: Version of Record

Link(s) to article on publisher's website:
http://cdsads.u-strasbg.fr/abs/1997ESASP.419..291S

MOLECULAR LINE EMISSION FROM PRE MAIN SEQUENCE OBJECTS

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ABSTRACT

We present some preliminary results obtained with the LWS G.T. programme on the study of young objects driving molecular outflows. In particular, we discuss the importance of molecular emission in these sources and address the role of the H_2O cooling.

1. INTRODUCTION

The FIR line emission of young stellar objects is mainly originated from two physical processes: the excitation from photoionised and photodissociated (PDR) regions (Wolfire et al. 1990) and the shock excitation produced by the interaction of supersonic winds with the ambient medium. Depending on wind velocity, magnetic field and ion density, two kinds of shocks with different FIR spectra are predicted from models: i) high velocity dissociative "J" shocks (e.g. Hollenbach & McKee 1989), in which molecules are dissociated in the shock front and atomic lines are the major coolers; ii) low velocity non-dissociative "C" shocks (Draine et al. 1983) in which the Alfven velocity is larger than the shock velocity and the magnetic field transmits energy in the preshock material. In "C" shocks H_2O is expected to form very efficiently and molecules are expected to be the dominant gas coolers. In the ISO-LWS range (Clegg et al. 1996) there are several atomic lines that are crucial to discriminate between PDR and shocks exitation and between the two kinds of shocks. Moreover in this range molecular lines emit most of their energy. Details on the observed sample and on the preliminary results obtained are given in Saraceno et al. 1997. Here we address only the results on the molecular line cooling in shocked regions.

2. MOLECULAR LINE COOLING

Table 1 lists all the observed objects with detected molecular lines for which it was possible to compute the cooling by means of a LVG model (Nisini et al. 1997). Only one Herbig-Haro object (HH), out of a sample of 17 (Liseau et al 1997) and three Herbig Ae/Be stars, out of a group of 10 (Lorenzetti et 1997), show molecular lines. For the HHs and Ae/Be stars the table is therefore representative of the relevance of molecular lines in these objects. On the contrary, for Class 0 and Class I sources the table is not statistically representative: we observed 15 Class 0 and low luminosity Class I sources and in nearly half of them we detected molecular lines. However, only for the three objects listed in the table it was possible, at the present level of data analysis, to compute the line cooling.

Source	Class	L_{bol}	$L_{[OI]}$	L_{CO}	L_{H_2O}	L_{OH}	L_{lines}	$\frac{L_{mol}}{L_{[OI]}}$	$\frac{L_{lines}}{L_{bol}}$
B335 FIR	0	3	0.002	0.004	<0.0012	...	0.006	2	2 E-3
IRAS16293	0	27	0.005	0.04	0.003	0.003	0.05	9.2	1.8 E-3
IC1396 N	I	235	0.1	0.63	0.17	...	0.9	8	3.8 E-3
HH54B	HH	-	0.0026	0.01	0.002	0.001	0.039	0.5	
R CrA	II	132	0.038	0.03	<0.0014	0.01	0.078	1.05	5.9 E-4
IRAS12496	II	50	0.005	0.008	<0.0015	...	0.013	1.6	2.6 E-4

Table 1: Line cooling; the luminosities are expressed in $L_\odot$

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In the 8th column of the table, the ratio between the total molecular line and [OI] 63μm line luminosities is given: we note that the cooling due to molecular lines is significant in all the sources, and dominates over the [OI] cooling in Class 0 and Class I objects. This result is a strong indication that "C" shocks are the main mechanism of excitation for this molecular emission.

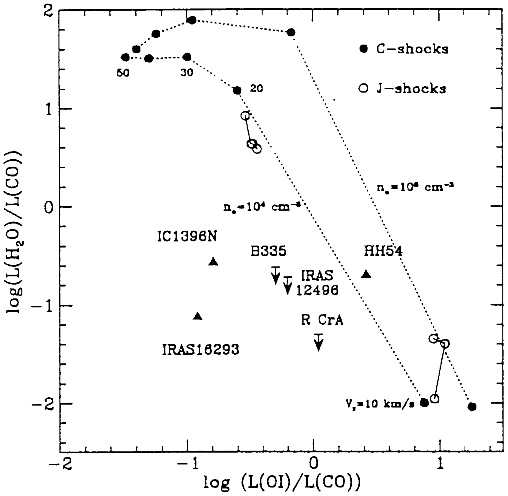

Figure 1: Line cooling predicted by "J" and "C" shock models

3. DISSOCIATIVE SHOCKS AND H_2O ABUNDANCE

Non dissociative shocks were expected to be "prodigious sources of far infrared water emission" (M. Kaufman and D. Neufeld, 1996) because H_2O forms very efficiently at temperatures above 400 K, which is typical of post-shock gas. Indeed, post-shock water abundances in excess of 10^{-5} are predicted by models (e.g. Draine et al 1983), with all the O not locked in CO transformed in water. Water has been detected in several objects of the LWS programme, but up to now only for three of them, namely HH54 (Liseau et al.1996), IC1396N (Molinari et al. 1997) and IRAS 16293 (Ceccarelli et. al. 1997) it is possible to compute the line cooling as reported in Table 1. For other three objects (B335, RCrA and IRAS 12496), for which H_2O has not been detected, we give an upper limit of the L_{H_2O} computed from the upper limit of the 179.5 μm o-H_2O line and assuming that CO and H_2O are emitted by the same region (same temperature, density and size). A comparison with L_{CO} shows that H_2O plays only a minor role in the thermodynamic balance in any of these objects.

This discrepancy between models and observations can be better seen from Fig.1 where a L_{H_2O}/L_{CO} vs $L_{[OI]}/L_{CO}$ diagram is plotted along with the predictions of "C" and "J" shock models. In "C" shocks the threshold temperature for H_2O formation is reached at velocities larger than 20 km s^{-1} where, in the figure, there is a jump of 3 orders of magnitude in the H_2O luminosities. For comparison similar curves are presented also for "J" shocks (open dots) for velocities of 30 and 50 km s^{-1} and pre-shock densities of 10^4 (bottom) and $10^6 cm^{-3}$ (top). If we compare model results with observations, we notice that, while HH54 agrees with both "C" and "J" shocks, all the objects clearly lie outside the regions covered by models. For IC1396N the situation is even worse because in this object most of the [OI] results from PDR emission (Saraceno et al 1997) and consequently its position in the diagram should move to the left. The observed discrepancy indicates a lack of water production in "C" type shocks; a possible explanation could be that in "C" shocks a large amount of oxygen is not available in atomic form but remains locked into grains or in O_2 and does not form water.

REFERENCES

Ceccarelli C. et al., "Star Formation with ISO", Lisbon, 24-26 June 1997

Clegg P.E. et al. 1996, A&A 315,L38

Draine B.T., Roberge, W.G. and Dalgarno 1983, ApJ 264,485

Hollenbach D., McKee C. 1989, ApJ 342,306

Kaufman M.J., Neufeld D.A. 1996, ApJ 456,611

Lada C. J., Wilking, B.A. 1984, ApJ, 287,610

Liseau R. et al. 1997, IAU Symposium N.182,111

Lorenzetti et al. 1997, "Star Formation with ISO", Lisbon, 24-26 June 1997

Molinari et al. 1997, "Star Formation with ISO", Lisbon, 24-26 June 1997

Nisini B. et al. 1997, "Star Formation with ISO", Lisbon, 24-26 June 1997

Saraceno P. et al. 1997, "Star Formation with ISO", Lisbon, 24-26 June 1997

Tielens A.G.G.M., Hollenbach D. 1985, ApJ 291,722

Wolfire M.G., Tielens A.G.G.M., Hollenbach D. 1990, ApJ 358,116