PROBLEMS OF MODELIZATION OF CIRCUMSTELLAR MATTER OUT OF EQUILIBRIUM

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1. Introduction

Circumstellar envelopes of young and evolved stars are responsible for many important phenomena concerning the exchange of matter, angular momentum, energy and maybe magnetic field between the core structure of stars and the interstellar medium. In particular, it is through them that matter enriched in heavy elements flows from evolved stars towards the interstellar gas, submitted to complex ordinary chemistry or photochemistry and condensation into solid particles.

Circumstellar envelopes are not a quiet medium : they are sites of complicated dynamics, chemistry, thermodynamics and energy exchanges, with typical values of basic parameters ranging in very large domains.

In envelopes of evolved stars, densities run from 10^{15} particles per cm^{-3} close to the star to a few particles per cm^{-3} far from it, with temperature of the orders of 2,000-3,000K close to the photosphere, 20,000K in the chromosphere, if any, and a few 10K in the outer parts.

Very different phases out of equilibrium are mixed in circumstellar envelopes; at least in their inner part, there is no simple symmetry : there may even be mixtures of phases in "partial" equilibrium (i.e. not in equilibrium with the other phases), cold and hot, optically thick and optically thin, dense and tenuous; moreover the phases can be distributed in layers with some (spherical for instance) symmetry or maybe in mixed clumps (Lafon, 1993).

According to likely theories, within 100 stellar radii the winds are highly structured at many different scales. However this is not obvious depending on the angular resolution. Indeed, due to the distance of closest stars, 100 stellar radii correspond to something like 0.1" whereas for early type stars this more likely corresponds to the milliarcsecond. This means that a resolution of a milliarcsecond could provide precise informations on the phenomena close to or on the surface of an evolved stars, but rather on the global structure of the envelope for an early type star (Lafon, 1993).

Finally constraints on the models describing the phenomena occuring within a few stellar radii from the star surface are fundamental for under-

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standing the physics and the structure of a zone close to the star, to which the farther parts of the envelope is very sensitive.

2. Two examples of phenomena out of equilibrium

2.1. Dust condensation

There is a controversy concerning the compatibility of dust with chromospheres observable around evolved stars : are chromospheres quenched by dust or is dust destroyed by chromospheric radiation? Or finally are dust and chromosphere simultaneously present?

Another point in discussion is the interaction of dust and shock waves (if any) in star envelopes : is dust nucleation and growth inhibited or stimulated by propagation of shock waves? In a similar way does dust make easier the dissipation of Alfvén waves?...and so on...

In any case, dust condensation and evolution occur obviously out of equilibrium and one should use cautiously quantities well defined only in case of equilibrium such as condensation temperatures or thermodynamical parameters of bulk material...(Lafon, 1991; Lafon and Berruyer, 1991).

2.2. Radiative shock waves : a summary of self-consistent non linear phenomena in media out of equilibrium

Strong radiative shock waves are an important phenomenon in atomic or/and molecular circumstellar atmospheres. Their structure is a summary of various media out of equilibrium in various ways.

The waves we talk about are propagating in highly collisional dense hydrogen atmospheres; investigations and modelization of shock waves have lead to amazing conclusions emphasized by recently available models (Huguet, Gillet and Lafon, 1992; Huguet, Lafon and Gillet, 1993a, b), as follows :

- The hydrodynamic discontinuity is included in a much larger consistent structure covering large distances on both sides.
- Behind the shock front there is no thermal equilibrium between electrons and heavy particles : the temperature can differ by orders of magnitude.
- The models are very sensitive to the presence or the absence of molecules which can still be present in gases at 100,000K.
- The medium is optically thin behind the front for the Lyman-α radiation, but at larger distances it is optically thick; before the front the medium absorbs the radiation in a "radiative precursor".
- The same structure exists for the Lyman continuum radiation, but over much larger distances, so that the Lyman-α dominated structure is included within the Lyman continuum dominated structure.

- The same structure exist also for the Balmer continuum, but the wake is optically thick at very much larger distances and the radiation crosses practically freely before the discontinuity.
- Specific unusual phenomena such as "three body recombinations" can compete with radiative recombinations in gases far from equilibrium of the populations of the energy levels, under very unusual and not well investigated ranges of parameters.
- Sites of line formation can be located in various place of such structures, in particular in places where the velocity deduced from usual spectroscopic analysis is much smaller than that of the shock front; accurate spectroscopic analysis would require good models (not still available!).

Thus, radiative shocks are an interesting "laboratory" of strange phenomena which can also be observed under other circumstances and may be the source of unexpected or misunderstood observations (in other atmospheric structures for instance).

3. The References

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