DECELERATED BLAST WAVES AND SELF-SIMILAR RADIATIVE COOLING IN SUPERNOVA REMNANTS

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Abstract

Radiative blast waves (BW) in supernova remnants (SNR) remain a difficult subject nowadays. The SNR expansion is usually decomposed in three stages [1, 2]. First the ballistic phase where the radius, R(t), of the SNR is proportional to the time [3], second the Sedov-Taylor regime [4] described by a well understood self-similar expansion, $R(t) = t^{\frac{2}{5}}$ (in spherical geometry), and third a radiative stage with $R(t) = t^q$, and 1/4<q<2/5, where the radiative cooling of the expanding flow produces the formation of a thin dense cold shell until thermal energy of all the swept gas is rapidly radiated and as consequence the thin shell enters in a Momentum-Conserving (MC) phase, with $R(t) = t^{\frac{1}{4}}$ [1,2]. In this former stage the internal pressure of the shell produces its expansion and the end of BW.

One of the main difficulty describing theoretically and self-consistently BW is that adiabatic shocked shell self-similar solutions do not exists for q<2/5 [5]. Hence in order to take into account, phenomenologically, the cooling rate, the ratio of specific heats for the gas behind the shock, has been chosen in the literature close to unity [6]. However, following this approach, even for the very small and unrealistic

values of the ratio of specific heats, the growth rate of instability is much weaker than the Rayleigh-Taylor growth rate and hence cannot explain in our opinion the instability and fragmentation observed in SNR.

In order to cover this lack of self-similar solutions in the third stage of SNR expansions we have relaxed the adiabatic assumption by including a cooling function A, only depending on time, $A = t^r$. The rigorous 1D self-similar solution is derived provided the exponent satisfy r=2q-3 where the expansion rate, q, can be less than 2/5. The solution is governed by a dimensionless cooling parameter Ac=Kp.v0.t0/Bo. Here Bo is the Boltzmann number of the flow, Kp is a mean volume Planck opacity, and v0 and t0 are the characteristic velocity and the hydrodynamic time, respectively, of the BW. Two main results arise. First, even with energy losses, the dynamics with q=2/5 (Sedov exponent) still exists and, second, for Ac larger than unity the profile of density decreases with radial coordinate, in contrast to the adiabatic case, and the growth rate of the instability becomes much larger than the one derived by Ryu and Vishniac [6].

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