Scaling astrophysical radiation hydrodynamics for the laboratory

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Abstract

In this presentation scaling laws (SL) connecting astrophysical radiation hydrodynamic phenomena to those created in laboratory with high energy/power facilities are examined. The traditional approach for SL is based on the use of dimensionless numbers and the invariance of their numerical values from a first phenomenon to a second one (Sedov 1946). This procedure is especially relevant when the physical processes under study are very complex and such that the equations for a mathematical model are not known. In contrast, when the equations governing the process can be derived, their invariance under Lie groups (Lie 1888, 1890 and 1893) provides a rigorous approach to get the appropriate SL although it is mainly used for the analytical integration of differential equations (DE) up to now (Ovsjannikov 1962, Bluman and Cole 1974, Ibragimov 1985, Olver 1986). Nevertheless, in laboratory astrophysics, invariance of the DE of the model has been performed to get scaled laboratory simulations of astrophysical phenomena in several areas ranging from supernova hydrodynamics to the interaction of strong electromagnetic fields with plasmas (Ryutov et al. 1999 and 2009, Ryutov et al. 2000, Ryutov et al. 2001, Ryutov and Remington 2002, 2003, 2006 and 2007). On the other hand, Takabe (Takabe 2001) provided a qualitative classification of similarity criteria based mainly of physical argumentations. In our presentation,

the two aspects, i.e. physical and mathematical, are used together in order to derive a hierarchy of SL obtained from various constraints on the degree of invariance of the DE (Bouquet et al. 2010, Falize et al. 2011) and in the less constraining cases additional degrees of freedom can appear making easier the production of a laboratory plasma that can be similar to the astrophysical process. This approach is illustrated on a few examples of astrophysical radiation hydrodynamics (radiative shocks, young stellar jets etc.).