Anomalous Tharmodynamics Regions (ATR) in Hot Dence Nonideal Matter

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Poorly known and recognized thermodynamic objects — Anomalous Thermodynamics Regions (ATR) — are under discussion as combination of two conjugated anomalous objects — *Entropic Phase Transition* (SPT) [1] and a region with regular, but *anomalous* thermodynamic properties [2]. Main feature of the ATR is *simultaneous negativity* of great number (usually positive) second cross derivatives of thermodynamic potential, e.g. thermal expansion coefficient, Gruneizen paramete, etc. The main consequence of this negativity is violated order and mutual crossing of great number of isolines e.g. isotherms, isentropes, Hugoniots, etc. It is the "forced delocalization" of some kinds of bound complexes (e.g. "pressure ionization", "pressure dissociation", etc.) that is the main "driver" of all physical transformations in both parts of ATR. It is multilayered structure of four thermodynamic surfaces: - $T(P,V), S(P,V), U(P,V)$ & $H(P,V)$(temperature, entropy, energy and enthalpy) - that is the unique "geometric" feature of these thermodynamic transformations in both parts of ATR.

The main sequence of the mentioned multilayered structure of $T(P,V), S(P,V), U(P,V), H(P,V)$ is anomalous ("returnable") form of the ATR-zone crossing by thermodynamic trajectories of shock, isothermal and isentropic compression and expansion.

The main sequence in turn of such form of ATR-crossing is anomalous Z-shaped (*"zigzag"*) form of dynamic mentioned above P-V trajectories. That leads in turn within ATR to *violation* of *global concavity* condition for the both adiabats and hence to possibility of *hydrodynamic instability* of the simple ("single-wave") form of the shock and isentropic compression and expansion. Two Entropic Fluid-Fluid phase transitions - in high T-P nitrogen and hydrogen - are under discussions and illustrations as the most important examples of the ATR.

Effect of so-called "shock cooling" is discussed as example of mentioned above anomalies on the base of our calculations with the use of First-Principle Equation of State (FPEOS) of Driver & Militzer [3]. There is enough reason to expect appearance of similar "shock cooling" effect in ATR region, which could be achieved in quasi-isentropic compression experiments on dense hydrogen, hydrogen-helium mixture and some other important fluid planetary substances.

[1] Iosilevskiy I 2014 *arXiv preprint arXiv:1403.8053*

[2] Iosilevskiy I 2015 *arXiv preprint arXiv:1504.05850*

[3] Driver K and Militzer B 2016 *Physical Review B* **93** 064101