From ICF to Laboratory astrophysics experiments relevant to the physics of young Supernova Remnants: ablative and classical Rayleigh-Taylor Instability in turbulent-like regimes

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The Rayleigh-Taylor Instability (RTI) occurs whenever fluids of different densities are accelerated against the density gradient [1], as it is the case for the ablated plasma accelerating the target ablator in ICF implosions [2]. The advent of MJ class lasers offers novel opportunities to study turbulent mixing flows in HED plasmas [3], for fundamental hydrodynamics or laboratory astrophysics experiments. A bubble-merger, bubble-competition regime [4] was evidenced for the first time in indirect-drive on the NIF thanks to an unprecedented long x-ray drive. A novel large-area, planar platform enables the capabilities to perform long duration direct drive hydrodynamics experiments on NIF [3,5]. In particular, four generation of RTI bubbles were generated at the ablation front as larger bubbles overtake and merge with smaller bubbles [5].

In the astrophysical context, RTI develops when blast wave drives stellar explosions [6] and in many other astrophysical contexts (jets, stellar interiors, classical nova outbursts to name a few). RTI plays also a role in Supernova (SN) explosions, either of Type Ia or II [7]. Radiative shocks are a fundamental aspect of astrophysical and high-energy-density systems because any fast enough shock wave becomes radiative [8]. However only few laser experiments [9] have addressed until now the effects and interplays of radiative shocks on RTI. We report on a series of experiments performed on the LULI2000 and GEKKO XII facilities studying the Rayleigh-Taylor Instability (RTI) in scaled laboratory conditions relevant for the physics of young Supernova Remnants [10]. Using a light CH foam (100 to 200 mg.cm^{-3}) as a deceleration medium, we performed, for the first time ever, classical RTI experiments on LULI2000. The RTI mixing zone is measured by PW transverse radiography (see Figure 1a) and its time evolution follows the expected scaling [11]. Complementary experiments are performed with modulated pushers accelerated in radiative gas-cells [8]. The radiative behavior is studied with high-Z gas filling (Xenon at 10 mbar), whereas the non-radiative benchmark case is done with Helium filled cells (at 330 mbar). The Atwood number [1], key parameter for RTI is kept constant by adjusting the filling pressure. The main diagnostics are in that case transverse optical ones (2D shadowgraphy and streaked optical pyrometers). The morphology of the "jet-like" RTI differs depending on the gas filling used (see Figure 1(c) and (d)). A conical shape is clearly visible for the jet propagating in helium

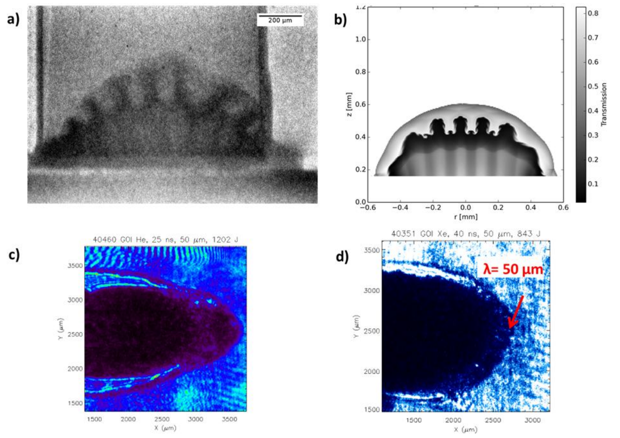

Figure 1: (a) and (b) Snapshots of RTI single mode growth in deceleration within a 200 mg.cm^{-3} foam. Side by side comparison of the experimental x-ray radiograph and the corresponding FLASH post processed simulation. (c) and (d) 2D transverse shadowgraphs acquired for helium filled (c) and xenon gas-filled cells at t = 25 ns and 40 ns respectively.

(whose half-angle gives a measurement of the Mach number), whereas the bow shock stays close to the accelerated pusher material in the radiative case. The analogy with adiabatic jets in astrophysics is currently being explored [12]. In both experiments, comparisons with 2D radiative hydrodynamic simulations performed with the FLASH code will be presented [13]. These experiments constitute the stepping-stone towards laboratory astrophysics experiments on LMJ.

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