DE LA RECHERCHE À L'INDUSTRIE

Non-modal hydrodynamic stability analysis for ablation flows relative to inertial confinement fusion

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Journée des thèses du CPHT

15/11/2018

Introduction

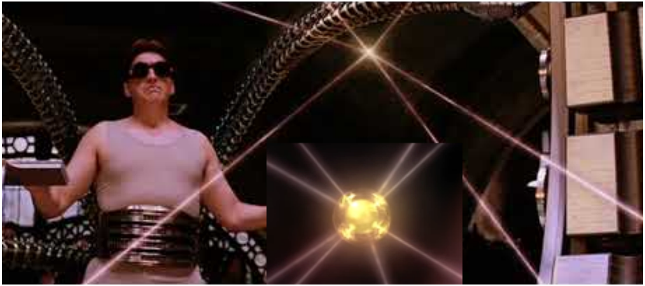


FIGURE – Otto Octavius, alias Dr. Octopus, achieves direct-drive inertial confinement fusion (ICF) in Spiderman 2, Raimi S., *2004*.

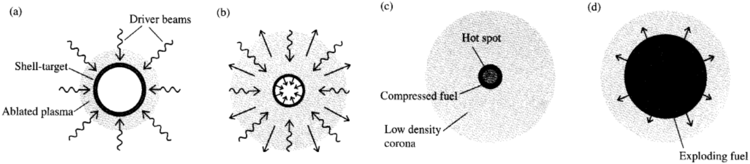
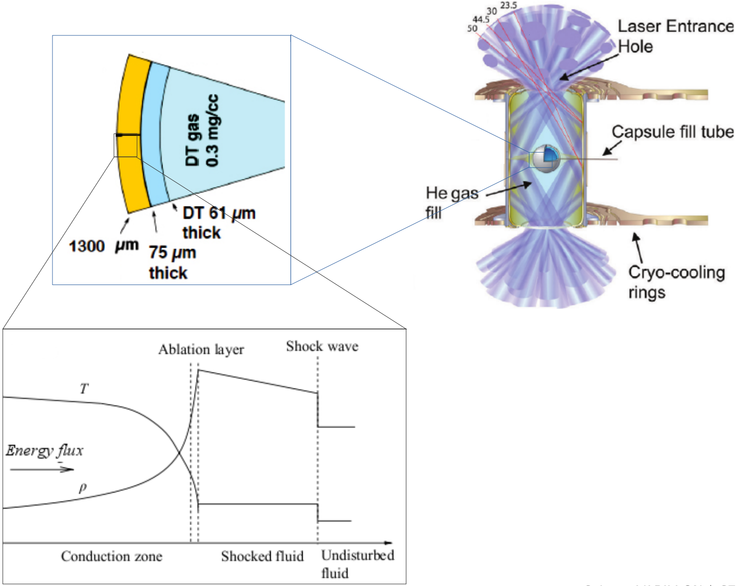


FIGURE – Successive implosion steps of an ICF target [Atzeni and Meyer-ter-Vehn, 2004].

Principles of inertial confinement fusion (ICF)



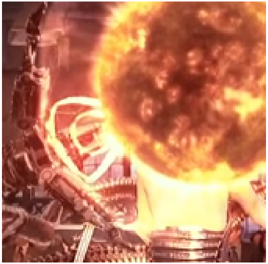
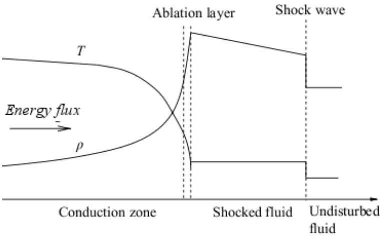


FIGURE – Spiderman 2, Raimi, S., *2004*.



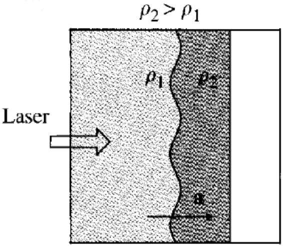


FIGURE – Ablative RTI [Atzeni and Meyer-ter-Vehn, 2004].

→ Loss of symmetry, damaging confinement
⇒ **Inhibit ignition**.

Goal :
How perturbations propagates ?
Which are the 'most dangerous' perturbations ?

Model and approximations

- $T_{surface} <\sim 10^6 K \rightarrow P_{rad}$ & E_{rad} neglected,
- $10^3 K \ll T_{surface} \rightarrow$ viscosity and thermal conduction neglected,
- Local thermodynamical equilibrium + optically thick body $\rightarrow \bar{\varphi} = -\bar{\rho}^{\mathrm{m}}\bar{T}^{\mathrm{n}}\partial_m \bar{T}$

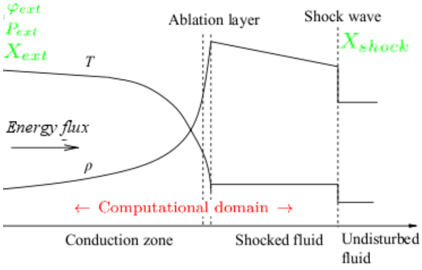
Perturbations are solution to linearized 3D perturbed Euler equation, with :

`diffusion | (hyperbolic) advection | source terms.`

One-dimension Euler equation for base-flow

$$\begin{cases} \partial_t 1/\bar{\rho} - \partial_m \bar{u} = 0, \\ \partial_t \bar{u} + \partial_m \bar{p} = 0, \\ \partial_t (\bar{T}/(\gamma-1) + \bar{u}^2/2) \\ \quad + \partial_m (\bar{p}\bar{u} + \bar{\varphi}) = 0. \end{cases}$$

$\rightarrow$



Analysis of perturbation dynamics in terms of propagating waves

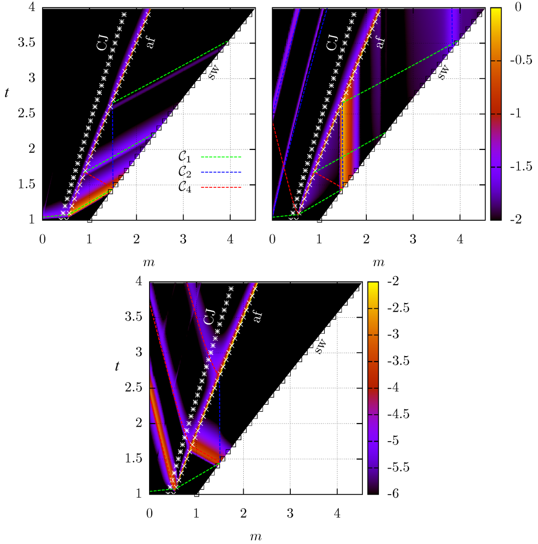


FIGURE – Projection of perturbations onto eigenmodes of the hyperbolic advection operator (log scale).

→ Solution close to linear hyperbolic waves

- Conduction region : *isothermal acoustics* and *heat-conductivity*,
- Post-shock region : *isentropic acoustics* and *entropy*.

→ **Supersonic heat-conductivity** linear waves.

Outcomes :

- simplified evolution equation,
- comparison with fundamental modes : acoustic, entropy and vorticity,
- analysis of ablation layer deformations.

Optimal initial perturbation (progressive wave local approx.)

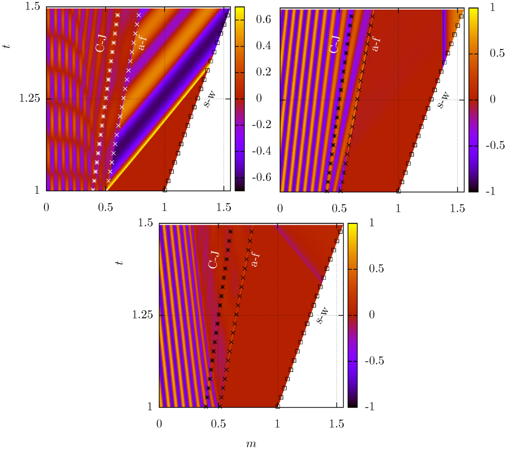


FIGURE – Projection of perturbations onto eigenmodes of the hyperbolic advection operator (slog scale).

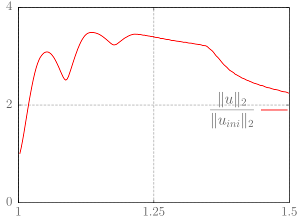


FIGURE – Transient growth on the norm of the perturbations.

Optimal initial perturbation :
→ superimposition of backward and forward acoustic waves.

Future results :

- Global modes,
- Optimal perturbation of arbitrary shape,
- Control (optimal boundary conditions)

Work

- Started in January 2017

Completed :

- Theoretical and preparatory work on non-modal methods (expression of the adjoint problem),
- Method changes in the numerical tool for computing perturbations (pseudo-spectral method),
- Analysis of perturbation propagation with the newly implemented methods,
- Progressive wave model for optimal initial condition.

In progress :

- Implementation of the direct-adjoint method to compute optimal perturbations.

Goals :

- Global mode stability analysis,
- Optimal initial condition, and optimal control *via* external perturbations.

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Thank you for your attention