Ecoulements radiatifs

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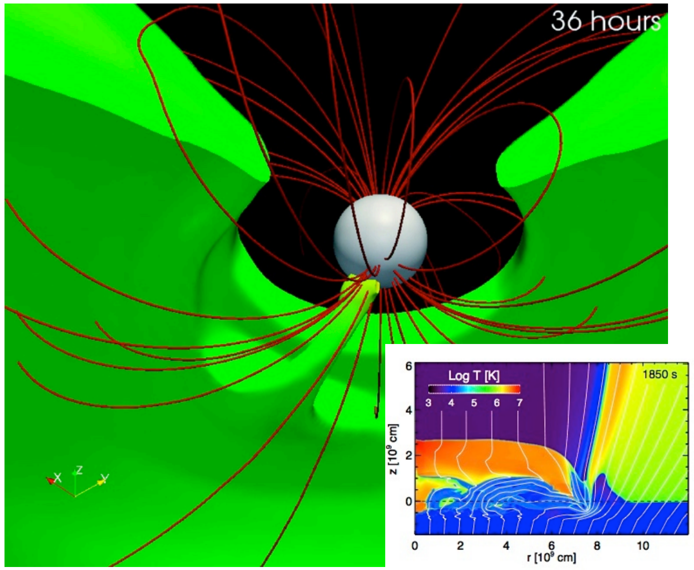
RADIATIVE FLOWS

Radiation impacts the structure of the plasma

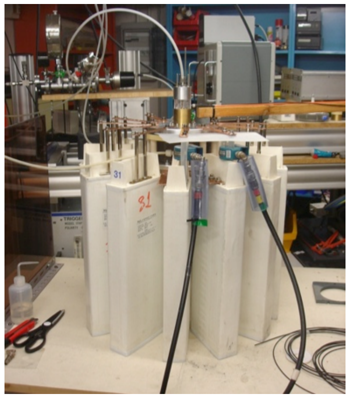
Usually in hot environments

Astrophysics

Laboratory
(high energy density)



Credit S. Orlando (Obs. Palermo)



Credit J. Larour (LPP)

Credit LMJ @ CEA

Scaling ? (Castor 2006)

Boltzmann Number

$$Bo = \frac{\text{Enthalpy Flux}}{\text{Radiative Flux}}$$

Radiation Flux dominated flow:
Bo << 1

Optical depth

$$\tau = \kappa\rho\, L$$

Optically thin : $\tau << 1$
Optically thick : $\tau >> 1$

Optically thin

Cooling rate, $\mathcal{C} = 4\,\pi\,\kappa_{Planck}\,B$ (if LTE)
$= \Lambda\,(T)$ (non LTE) (erg/cm³/s)

$$Cool = \frac{ut_{cool}}{L} = \frac{1}{4}\frac{Bo}{\kappa_P \rho L}$$

	L (cm)	N (cm^{-3})	T (K)	U (cm/s)	B_o	τ	Cool	Re	M
Stell. Atm.	10^9	10^{15}	10^4	10^7	**0.06**	**1**	**0.001**	**5 10^{12}**	**10**
Stell. wind	10^{12}	10^{11}	10^5	10^8	**3 10^{-6}**	**0.01**	**3 10^{-5}**	**5 10^{10}**	**40**
Short pulse laser	0.001	10^{24}	10^7	10^8	**0.3**	**0.01**	**5**	**10^3**	**4**

Castor : « the odds that a given astronomical environment can be simulated in the laboratory are not good. However, the odds that a given laboratory environment has an analogue in astronomy are much better. »

No SCALING FOR SPECTROSCOPY

2 approaches :

- *Approximate scaling*

Accretion
1) on white dwarfs
(Falize & al.)

2) on T-Tauri stars in the lab. *(Ciardi & al.)*,
Effect of radiation cooling, instabilities, collimation by B.

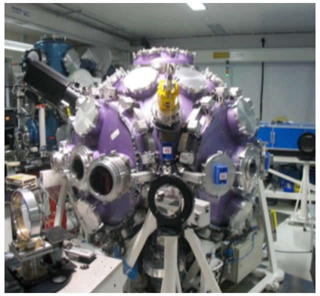
- *Study of physical processes in the presence of radiation & link to astrohysical situations*

Radiative shocks : accretion on Young Stars, SN breakthrough ..;
(Stehlé, Michaut, Larour)

Rad. mediated instabilities
1) Vishniak *(Michaut et al.)*
2) Rayleigh Taylor *(Hungtigton)*)
of *interest for SN explosion and their link to SNR*

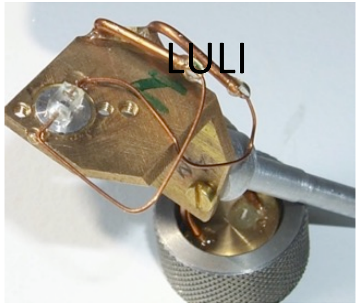
4 piliers

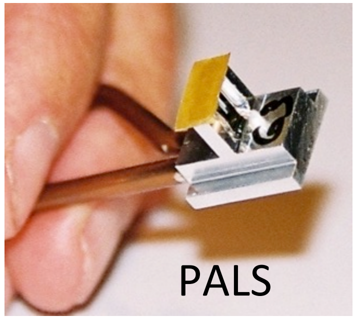
kJ, ns)



$10^{14} – 10^{15}$ W/cm^2

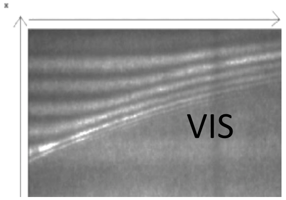
cibles



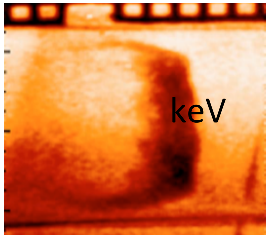


mm

Diags



Bouquet et al, 2004,



Rheighart et al. 2006,

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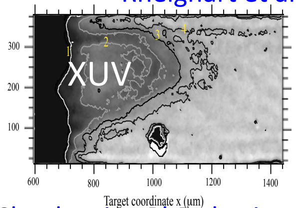
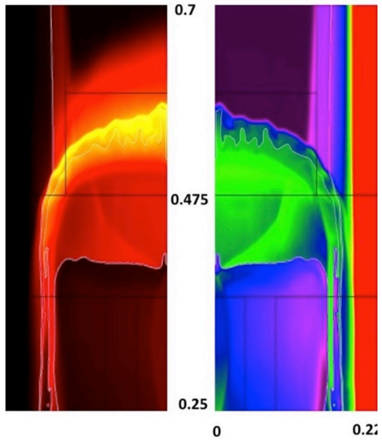


Chaulagain. PhD thesis 2015

Multi λ

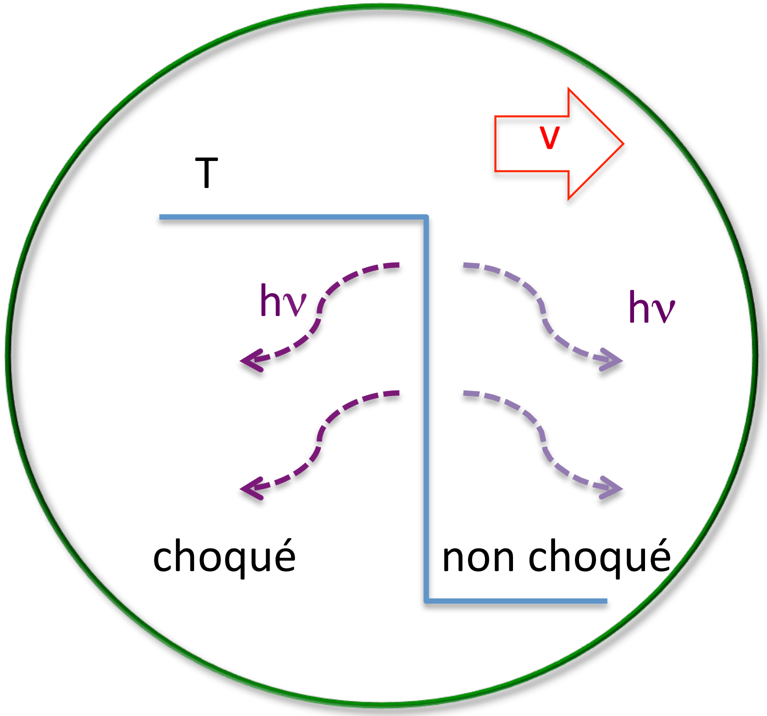
Simulations & theory



Cotello et al. 2015,

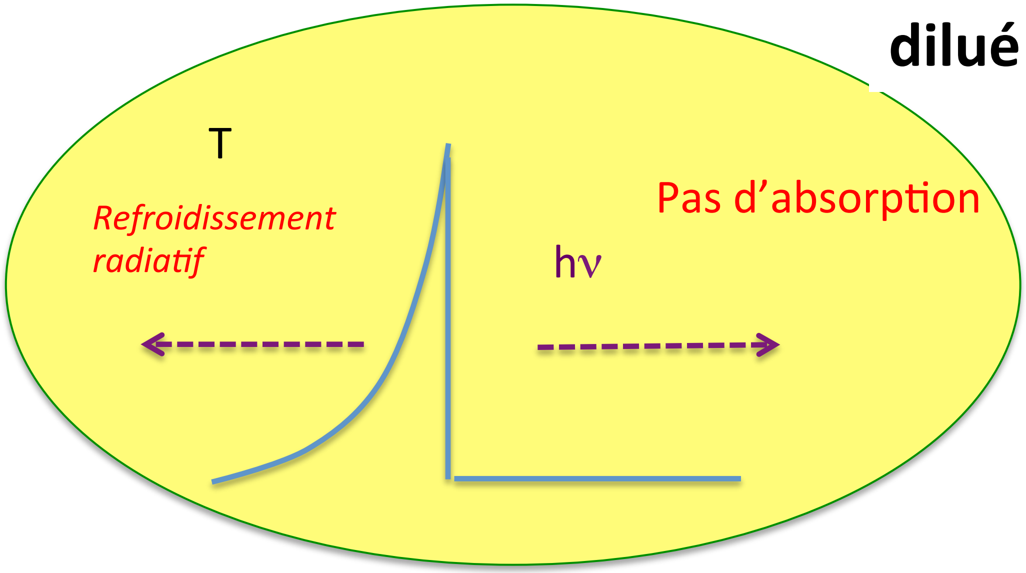
2D RMHD

Chocs radiatifs: 2 familles

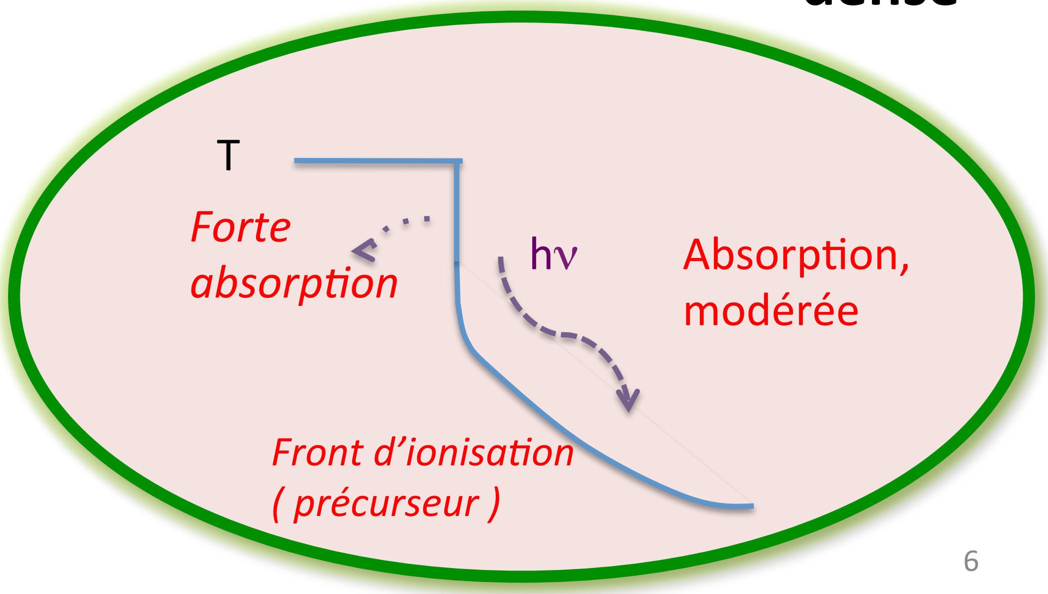


et toute une classification pour chacune de ces familles

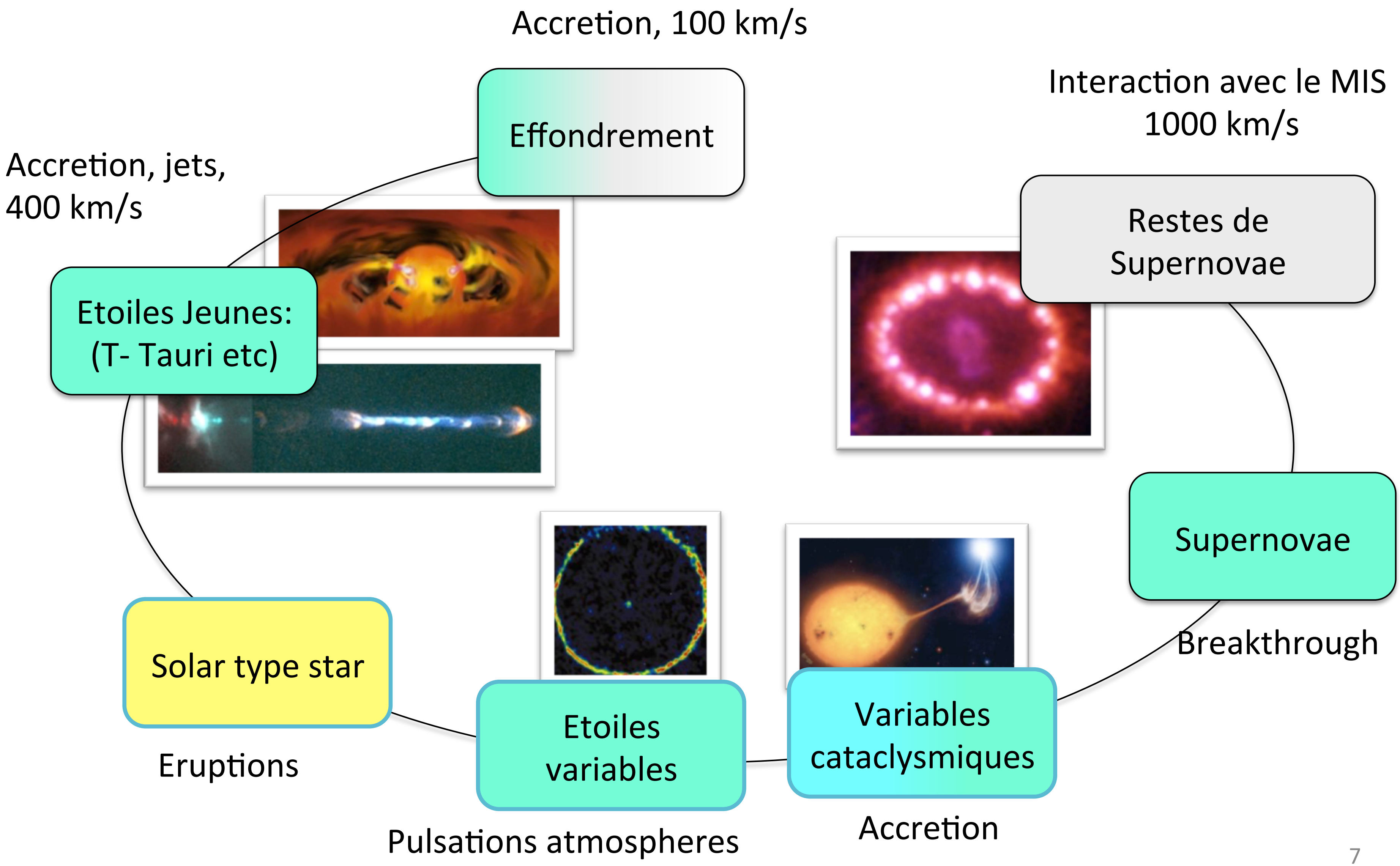
Milieu dilué



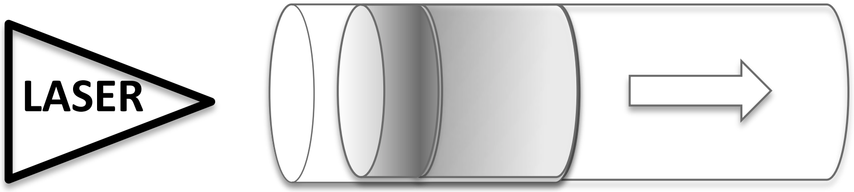
Milieu dense



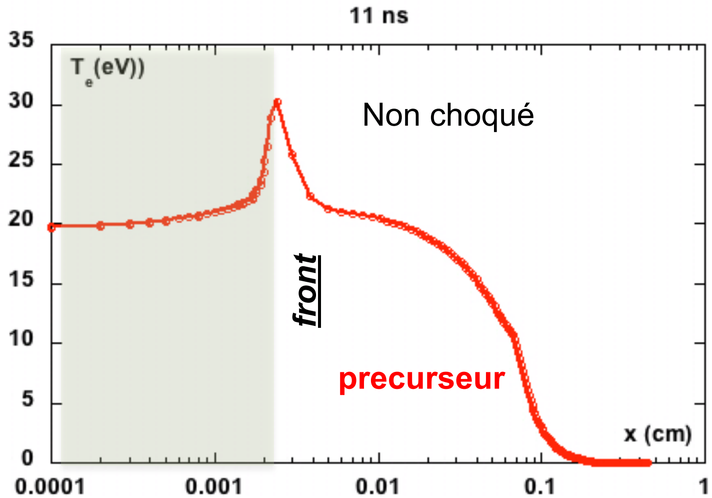
Durant l'évolution stellaire



1D setup



France : précurseur radiatif



LULI en 2000 (100J @ 3ω) Xe ~ 0.2 bar), **65 km/s**
Analyse du **précurseur radiatif**
Fleury 2002, Bouquet 2004, + autres exp.

Désaccord entre simus 1D et expérience :
- Simus 2D : FCI2 et post traitement en transfert radiatif) (*Leygnac 2006*).

PALS 2005-2015 (100 J @ 3ω): **60 km/s**
- Pertes radiatives aux bords du tube
- Régime quasi stationnaire

Simus 2D HERACLES (*Gonzalez 2007*, 2009)
- Estimation de l'albedo des parois

Lasers kJ :
LULI , PALS

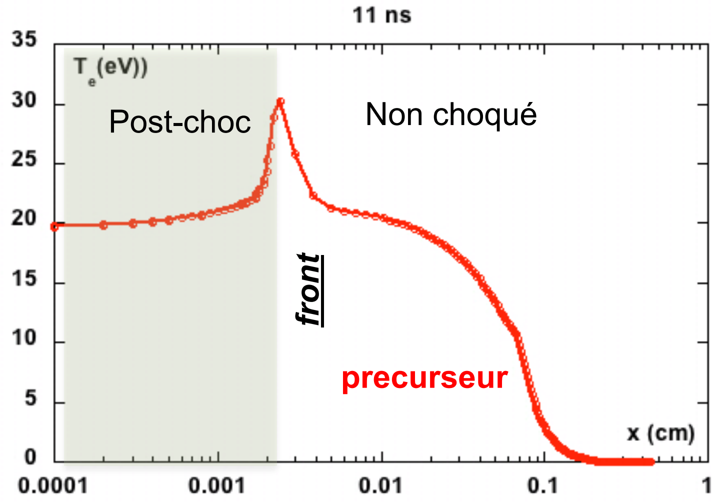
Accrétion protostellaire
- CTT (*Matsakos et al. 2013*)
  -> 2D (*Matsakos et al. 2013, PLUTO*)
  -> Couplage rad. (de Sa, Chieze, ASTROLAB)
- coeurs pré-stellaires (*Commerçon et al 2011*)

plus grandes vitesses,

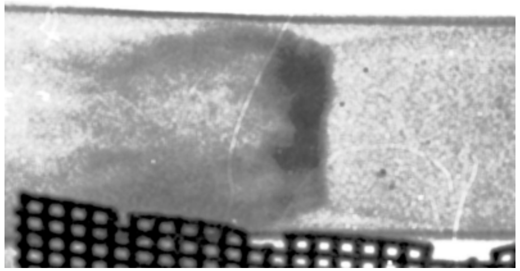
USA : post choc

OMEGA
1) Etude du post choc par radiographie X : le front de choc reste très collé au piston -> **collapse radiatif**
Simulations 1D (Hyades) et 2D (FCI2) *(Reighard et al 2006), Suzuki Vidal et al. à venir*

2) Effet du rayonnement sur les parois *(Doss et al 2009)*



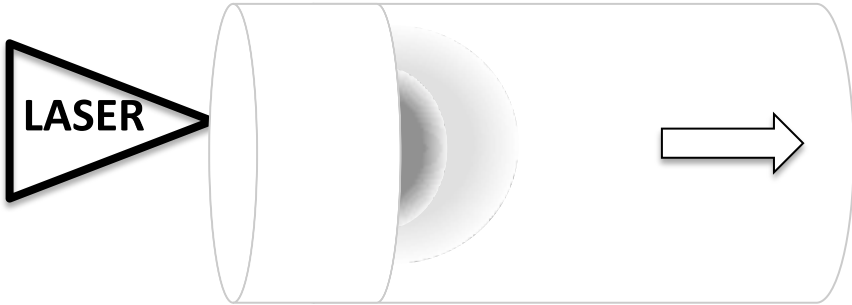
Développement du centre CRASH pour simuler les chocs radiatifs *(Van der Holst 2011, Fryxell et al 2012)*



Radiographie éclair @ OMEGA

Laser multi kJ : OMEGA

2D setup

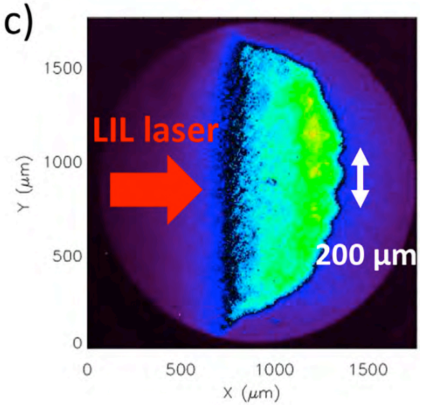


LIL & GEKKO (curvature effect)

LIL (4-8 kJ at ω), 160 km/s Kr, Xe (50 mbar)
(Michaut et al. ILP report 2015, Casner 2015)

GEKKO XII, 1 kJ at 3ω, 200 km/s Xe (50 mba
(Diziere 2011)

The shock is curved
(also noted in earlier studies at LULI)

c)


ORION (post shock & precursor)

1.6 kJ at 3ω, 80 km/s Kr, Xe (0.3 bar, Ar, Kr)

Post shock & precursors identified
Instabilities, radiative collapse

(Suzuki Vidal 2016)

Lasers multi kJ : LIL, GEKKO, ORION

Perspectives

Chocs isolés – approfondissement

- Explorer les régimes radiatifs (-> transition vers chocs optiquement minces et refroidis notamment *-> jets stellaires par ex*.)
- Mesure de $\mathbf{T_e}$ mais aussi $\mathbf{T_i}$ cad mieux résoudre le choc .
- Benchmark complet
- Signatures **spectrales** *(et test codes)*
- **Instabilités + rayonnement** *(SN notamment)*
- **Effet de B.**

Chocs et interactions

- Interaction de chocs (PALS, *ORION)*
- *Chocs sur obstacle (LMJ à venir)*

ORION's chamber

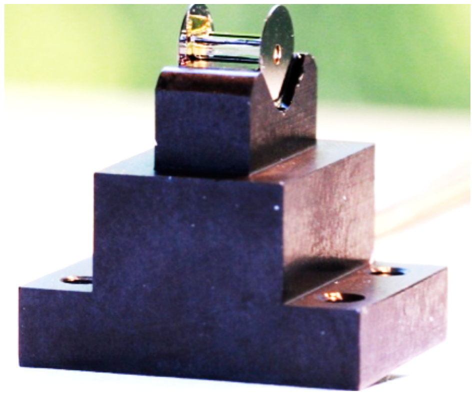
Forces et opportunités

Une dizaine de groupes (théorie et expérience)
France : LULI, LERMA, CEA-DAM, CEA-AIM, LUTH, LPP…
Etranger : Rochester, LLNL, PALS, GEKKO, Imperial College, IFN …
De nombreuses thèses expérimentales et numériques

- Filière cibles spécifiques *(GEPI)*
- Dévts numériques en cours *(transfer 3D, IRIS; HADES 2D)*
- Table top-experiment *(LPP)*.
- Diagnostiques originaux *(radio éclair à 21 nm)*

- Besoin d'installations kJ
- Perspectives LIL/LMJ

- Confrontation observationnelles : *pour l'accrétion, ATHENA, SPIROU, ARAGO*



Cibles : GEPI, LERMA