JET Simulations, Experiments and Theories

Laboratory Astrophysics: Episodic Jet Ejection and Radiative shock waves

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MARIE CURIE ACTIONS

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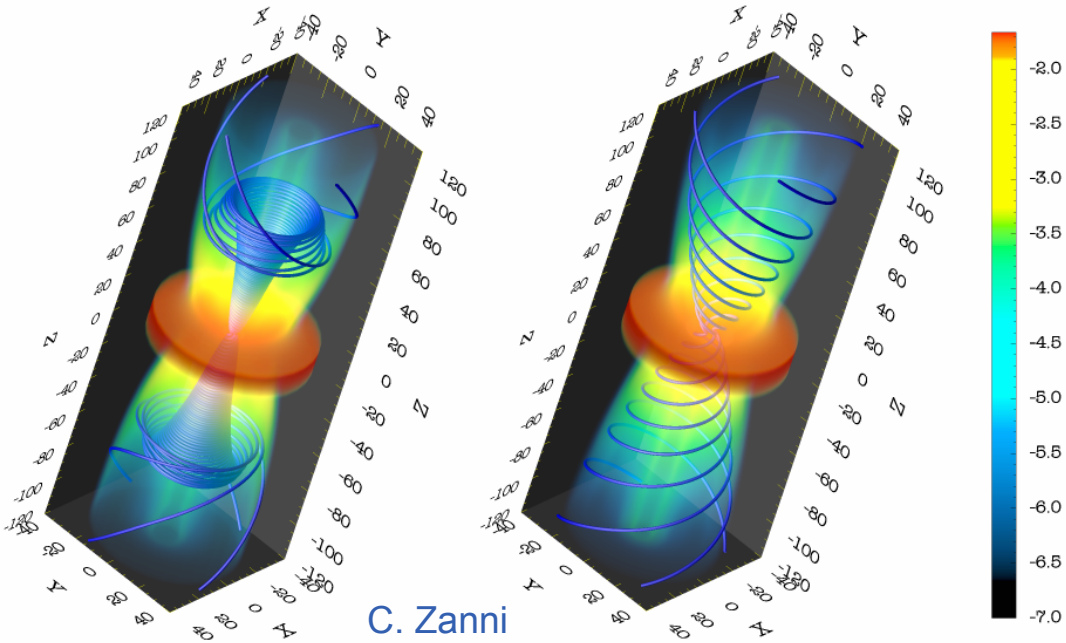
Layout

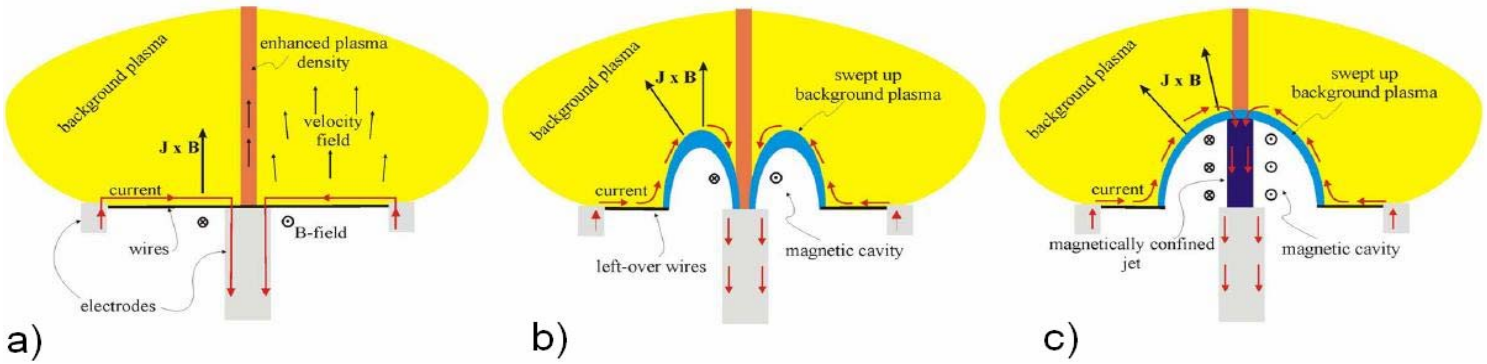
- **Introduction on radial Z-pinch**
  - General overview of general Z-pinch Laboratory Astrophysics concepts
- **Episodic Ejections**
  - Astrophysical motivations
  - Experiment set-up and lay-out
  - Code validation
  - Current path and B-field trapping
- **Episodic Ejections in Ambient Medium**
  - Motivations and set-up
  - Astrophysical relevance
  - Evolution
  - Code Comparison
  - Shock-structure
  - Shock evolution
  - **Conclusions and Future Development**

Wire Array & Astrophysics



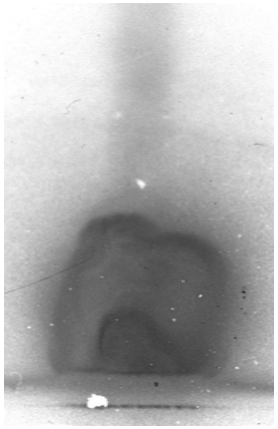
C. Zanni

- Radial Wire array Z-pinch set up
- 16 Aluminium Wires
- 1 MA current, 240 ns rise time
- JxB – Lorentz Force
- Scaling to astrophysical jets

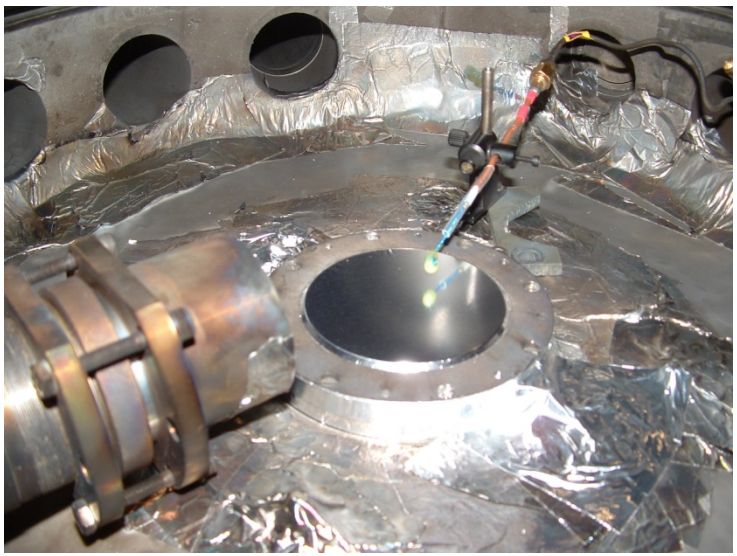


Astrophysical Motivations

- HH 111
- 0.32 light years ~ 20000 AU



- HH111
- Pulsed jet structure
- Bow-shock
- HD problem, or MHD problem?
- Possible structure of B-field
- Experiment that can reproduce these pulsed knots



Evolution

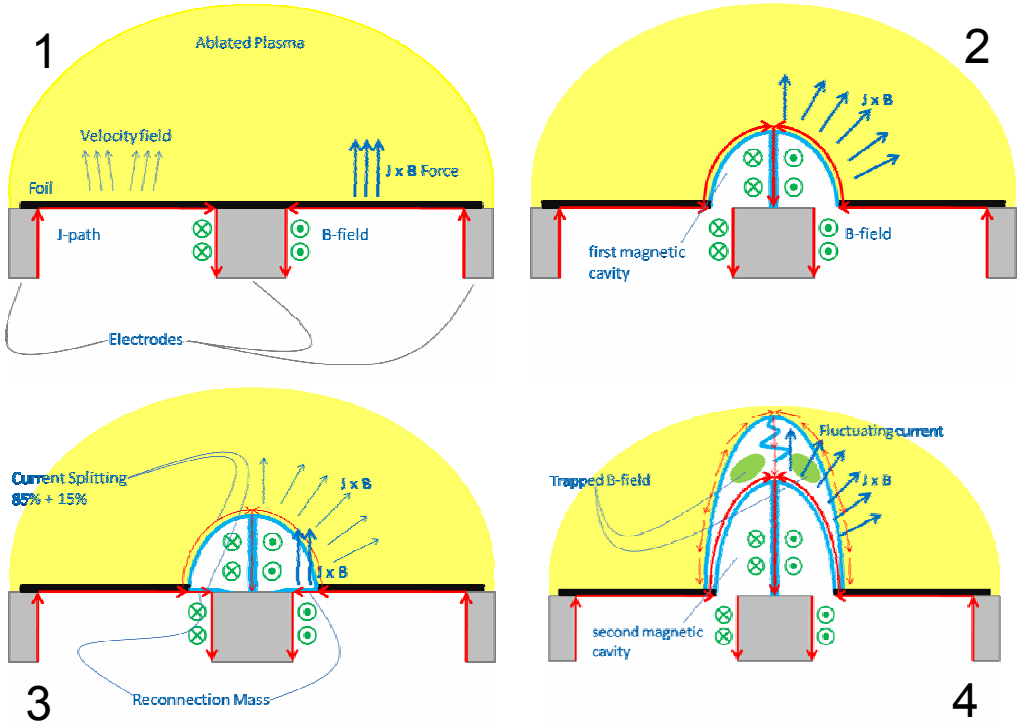
- The evolution may be subdivided in 4 broad phases:

1. Ablation.

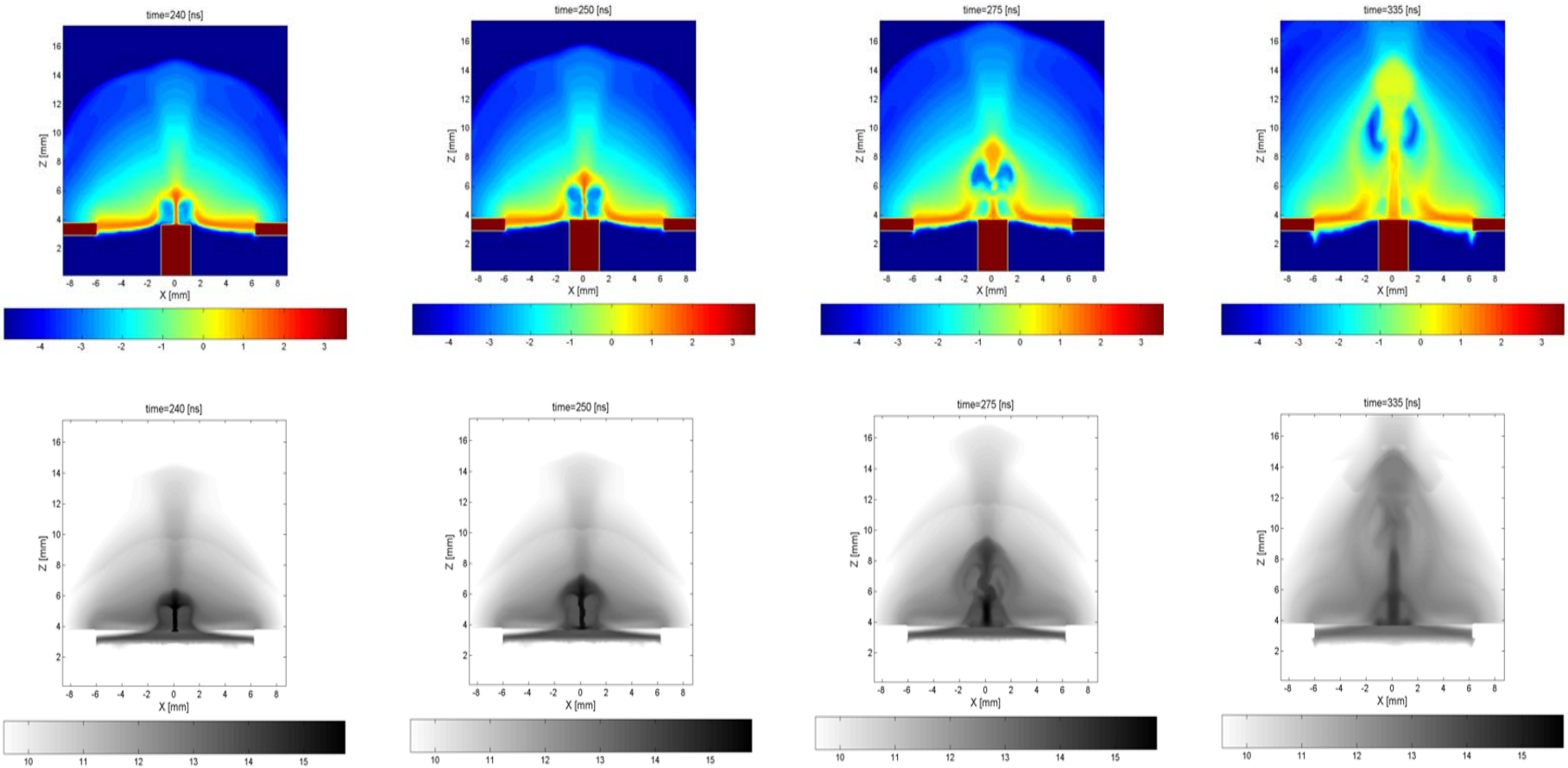
2. Bubble formation. The B field pushes the foil upward and generates the first plasma bubble.

3. Reconnection.

4. Second bubble formation. Extra bubbles and B-field trapping.



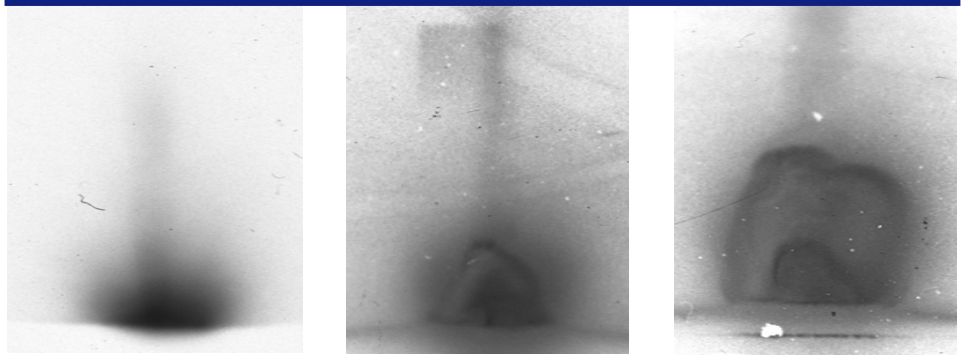
Evolution

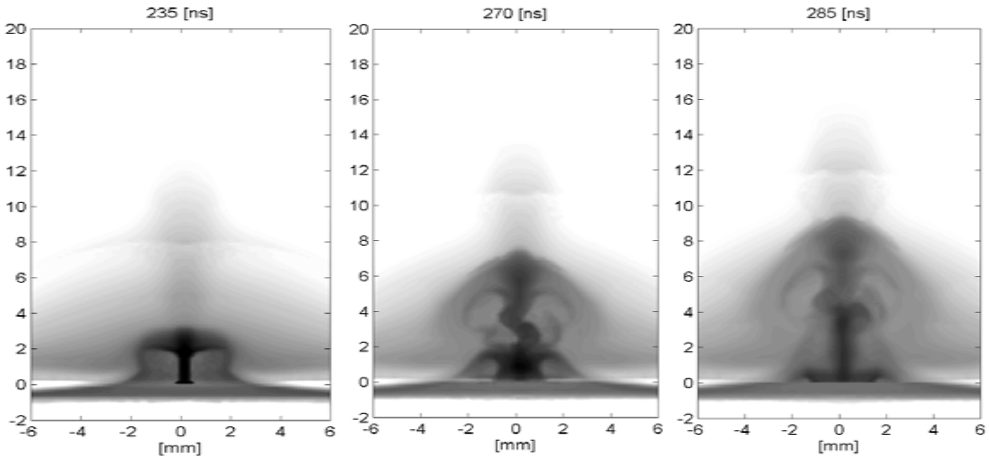


XUV -Comparison

- The mass is introduced artificially
- EOS are not modelled in the code
- Numerical simulations show much more stable Z-pinch
- The agreement beaks quit early in time
- In both cases the HD precursor is clearly visible

Experimental XUV

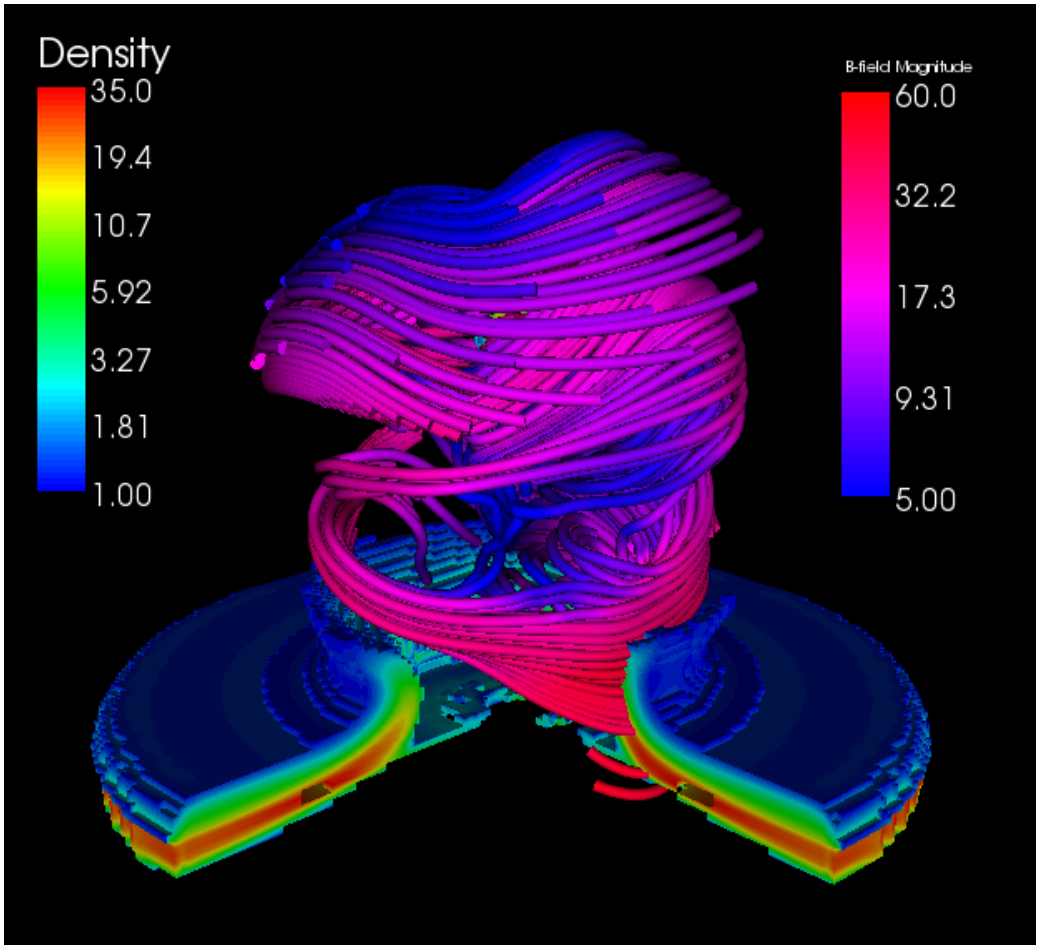




Synthetic XUV

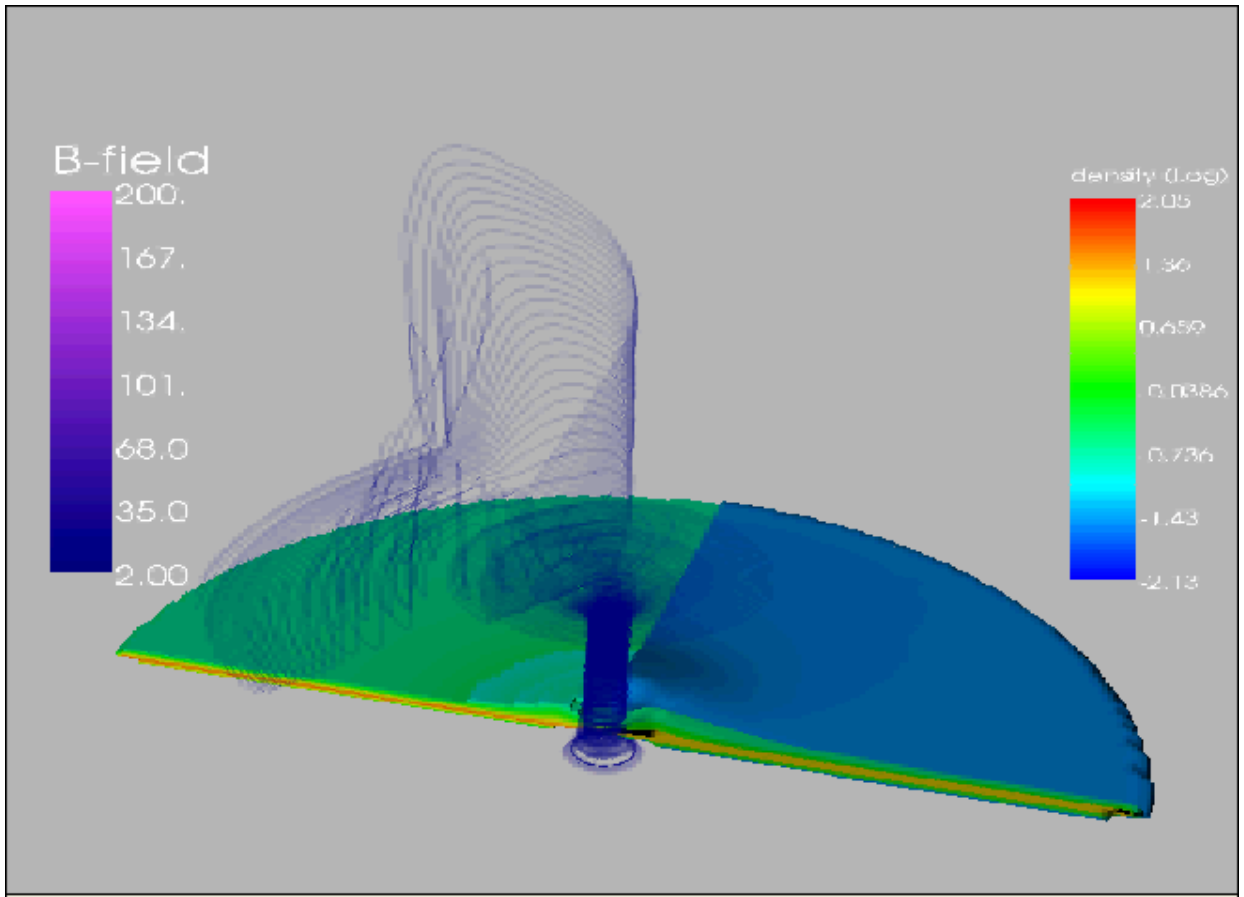
B-field

- reconnection problem
- B-field lines can break and close, otherwise they would eventually extend to infinity
- trapped magnetic field in between bubbles (~55 T at 285 ns).
- The structure of the magnetic field is mainly toroidal showing the presence of a strong axial current (0.5 MA).
- B-field trapped in between bubbles: MHD equations needed to explain such phenomenon.



B-field

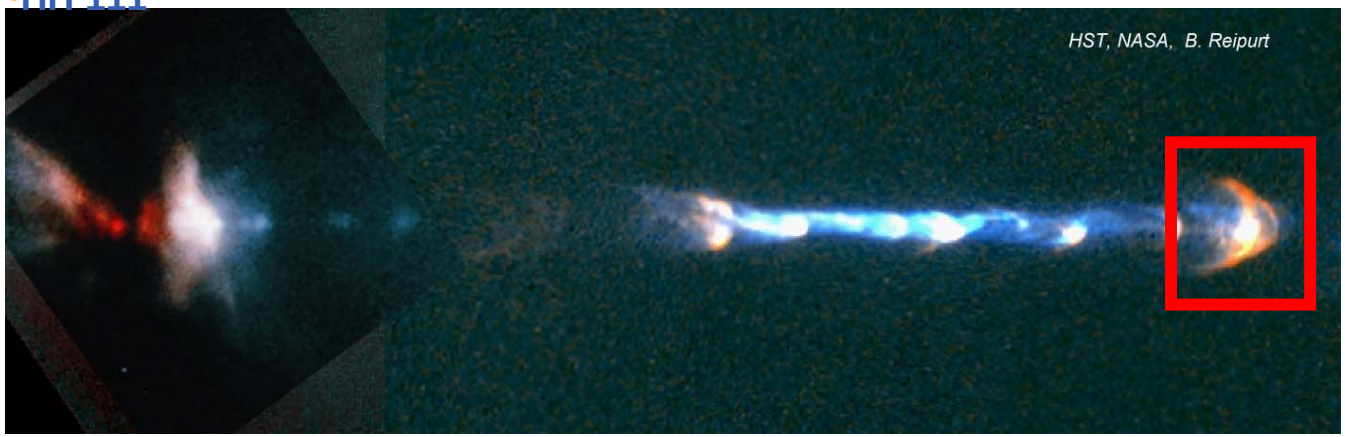
- The movie shows the evolution of the magnetic field.
- The structure of the magnetic field is toroidal, because of the system geometry.
- The magnetic field stays trapped in between bubbles.

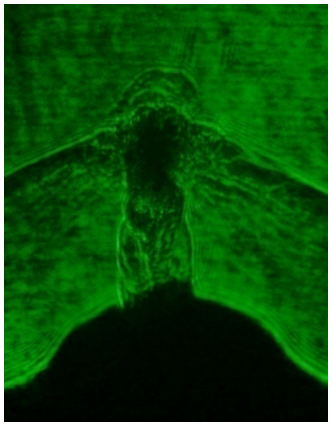


foil_11_cut.avi

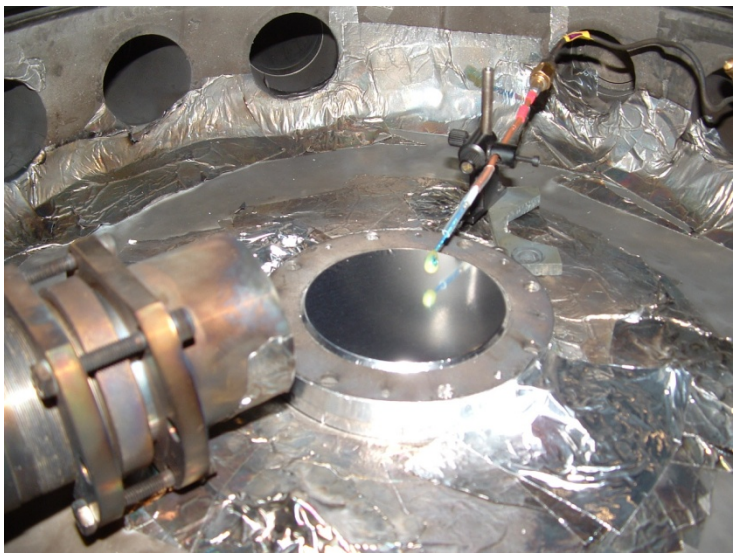
Astrophysical Motivations

- 0.32 light years ~ 20000 AU
- HH 111





- H111 Bow-Shocks
- Cooling Effects
- Radiation emission and radiation transport
- Two Gas interaction



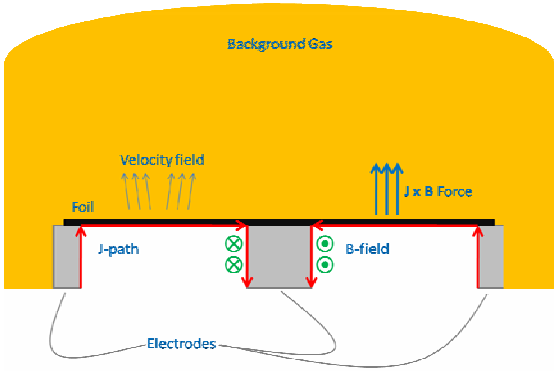
Evolution

- The evolution may be subdivided in 4 broad phases:

1. The foil starts ablating from the top surface.

2. The foil develop a two-component structure. The ablated mass is initially driven, later pushed, into the background gas (Ar).

3. A conical shock structure is formed. A snowplough model applies for the background gas. 3D Mach stems are formed.



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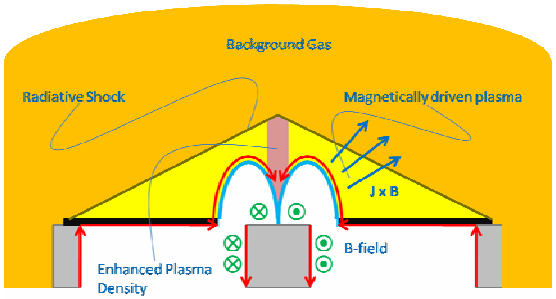

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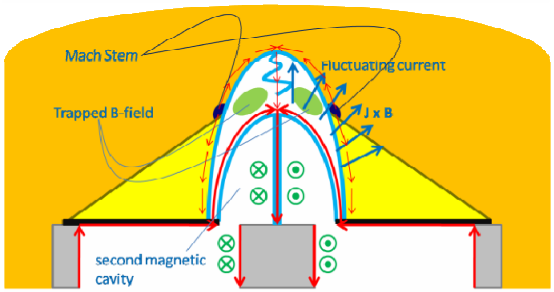
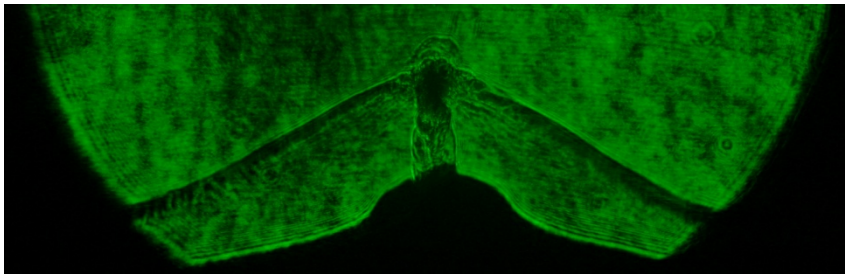
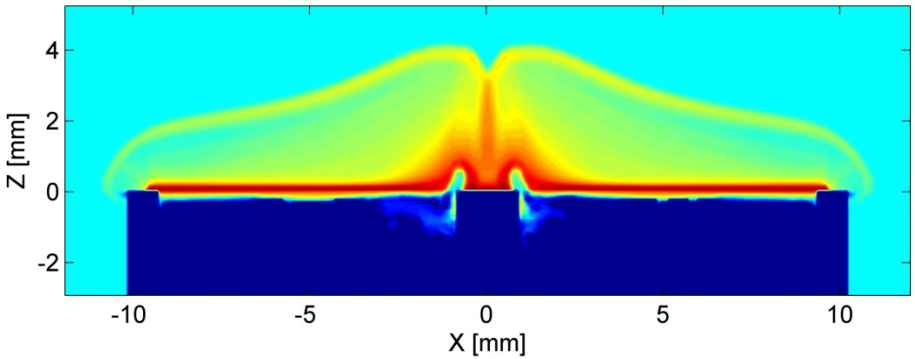


3

Code-validation

- The shock is generated by the ablated top layer of the foil that thanks to the Lorentz's force is pushed in the ambient gas.
- resolution used 75 μm
- The HD-jet is clearly detectable
- Experimentally Shadow is characterized by a ~60° shock.
- Simulations shows an angle of ~68°
- Experimental offset 1.2 mm

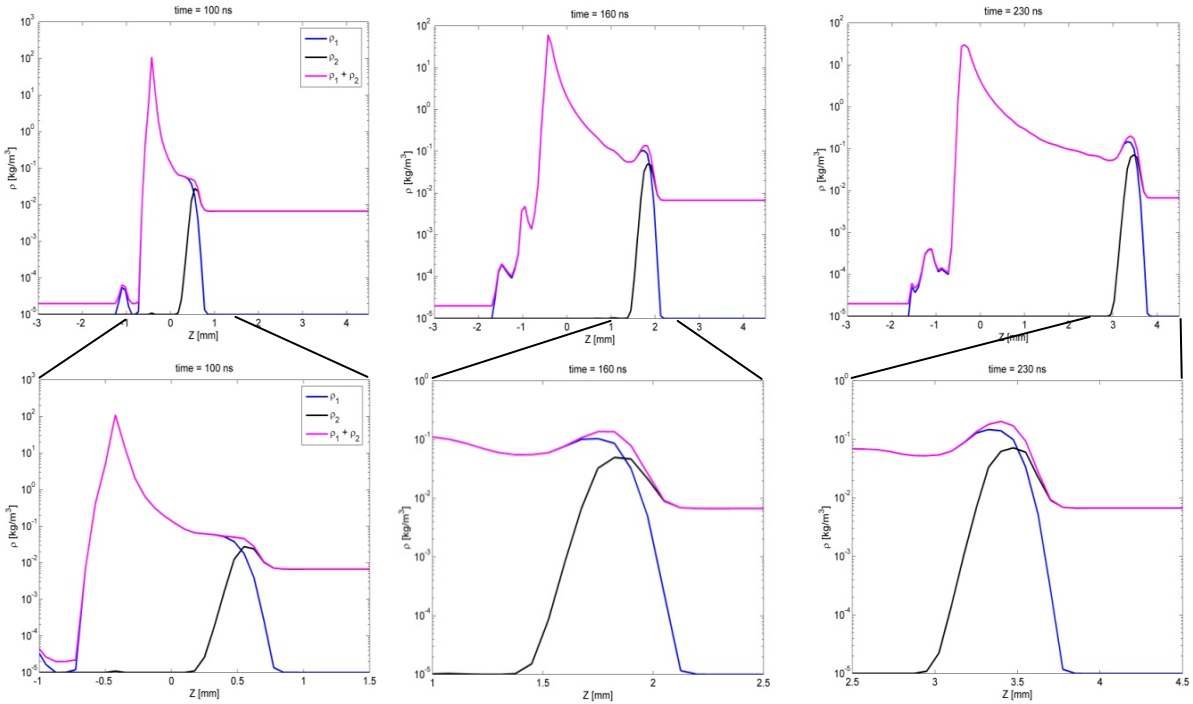


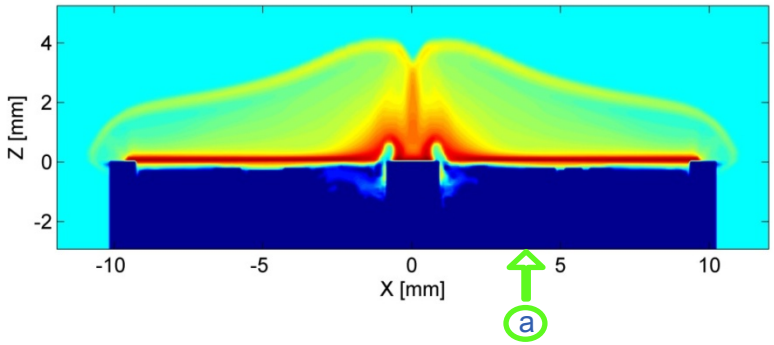


Shock-Characteristics

- Frame at 100 ns – 160 ns – 220 ns
- 110ns: ρ_1=70%; ρ_2=30%
- 160ns: ρ_1=64%; ρ_2=36%
- 230ns: ρ_1=76%; ρ_2=24%

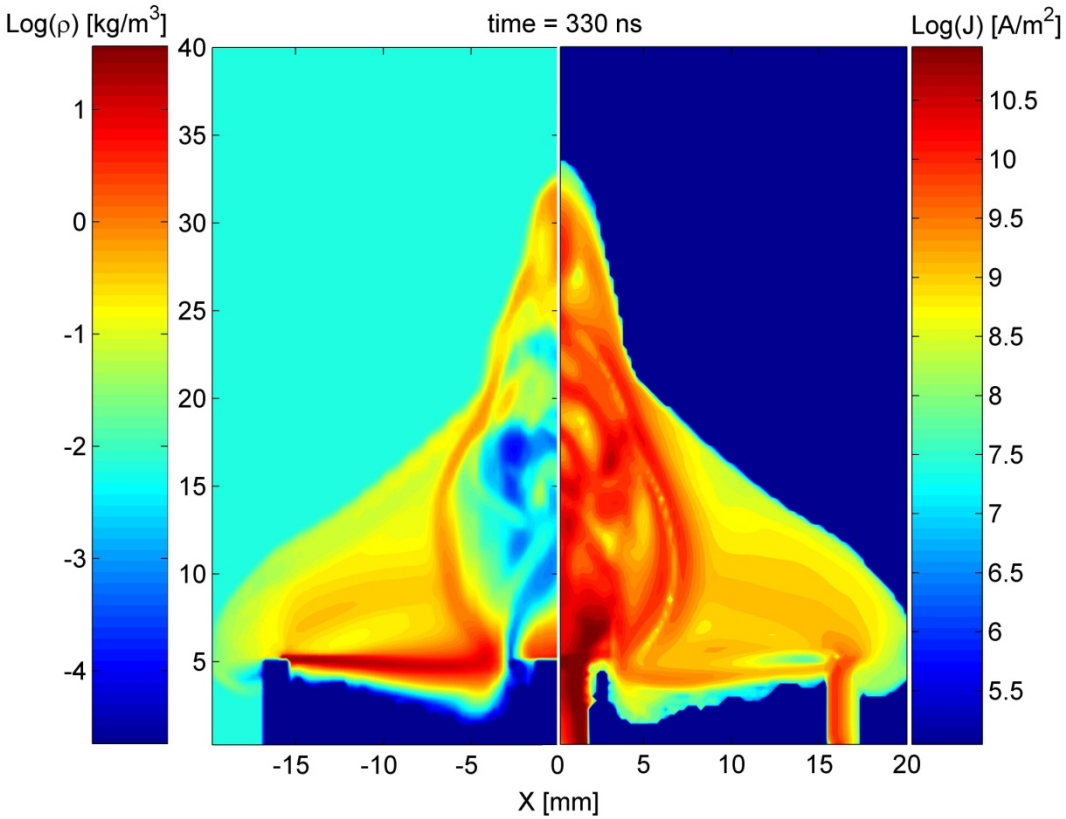
- Shock-Front velocity 50 km/s
- Snowploughed mass is very small, probably due to the low density background





Current Path

- The current flows initially on the first bubble edge
- Secondly it follows the second bubble edge
- The ambient gas does not offer any reconnection paths.



Conclusions

- We have analyzed the foil set-up: ablation process – current path reconnection – magnetic flux trapping.
- The episodic emission in an ambient gas has been investigated as well. Both ablation and melting process have been studied.
- More detailed simulations are needed to explore the magnetic flux trapping in between bubbles and the collimation effects it might offer.
- The importance of the ambient gas for collimation and emission needs further study.

The end!

ANY QUESTIONS?