Proton-diagnostic performance in laser-driven hydrodynamics experiments

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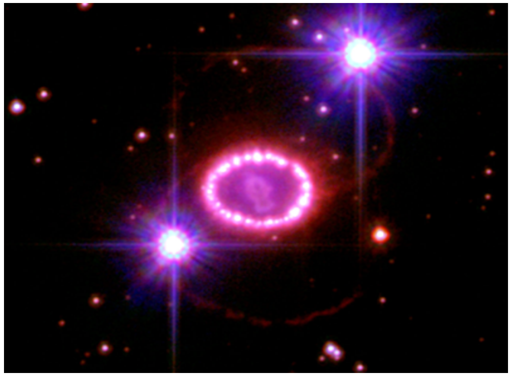
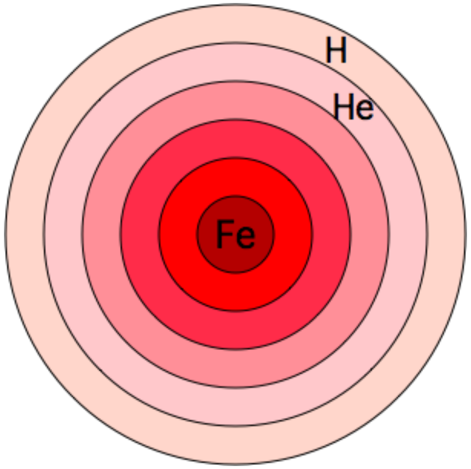
SN1987A motivates our experiment

- **SN1987A, a recent and proximate core-collapse supernova (SN)**
- **Light signature observations did not agree with models**
- **Rayleigh-Taylor unstable behavior proposed as mechanism**
- **System behaves such that it can be scaled directly to a lab experiment**



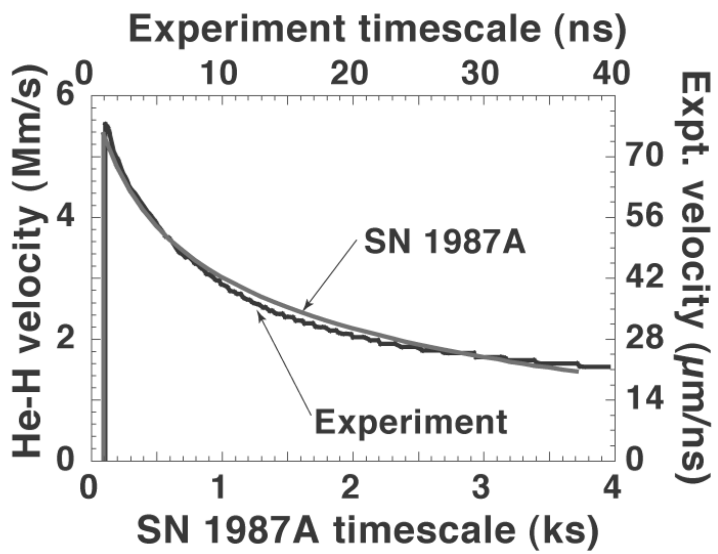
SN1987A, Hubble Space Telescope



Stellar Composition

The experiment can be scaled to the supernova using Euler similarity

	SN1987a	our exp’t
r	10^{11} cm	10^{2} μm
ρ	10^{-2} g/cc	1 g/cc
p	10 Mbar	1 Mbar
t	1000 s	10 ns



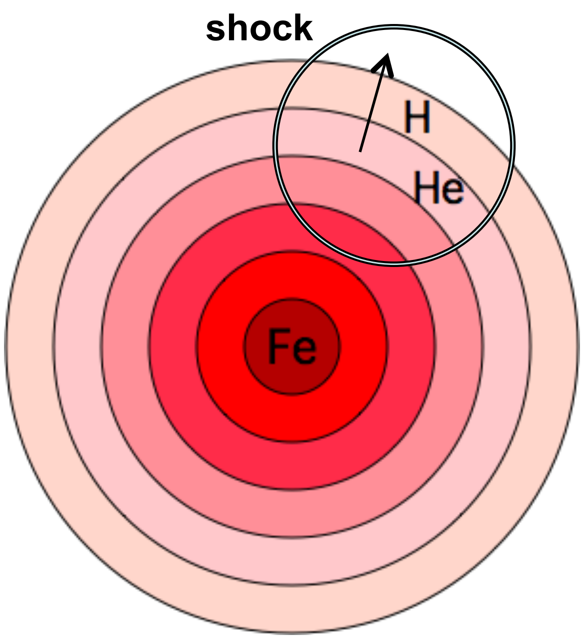
Caveat: this argument is only valid for two systems of Euler fluids

Relevant conditions:

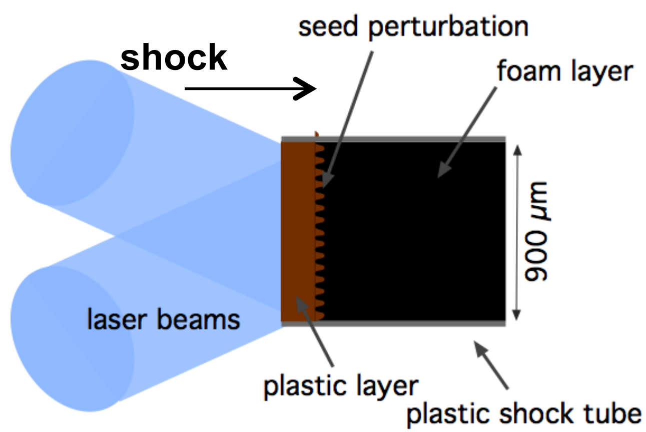
- **Collisionality**
- **Viscosity**
- **Heat conduction**
- **Radiative flux**
- **E&M forces**

Ryutov, ApJ 1999

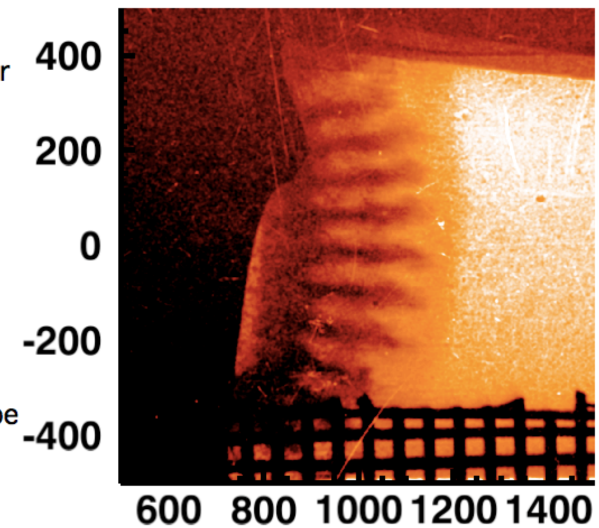
Local physics is similar to H/He interface during the supernova explosion



supernova sketch

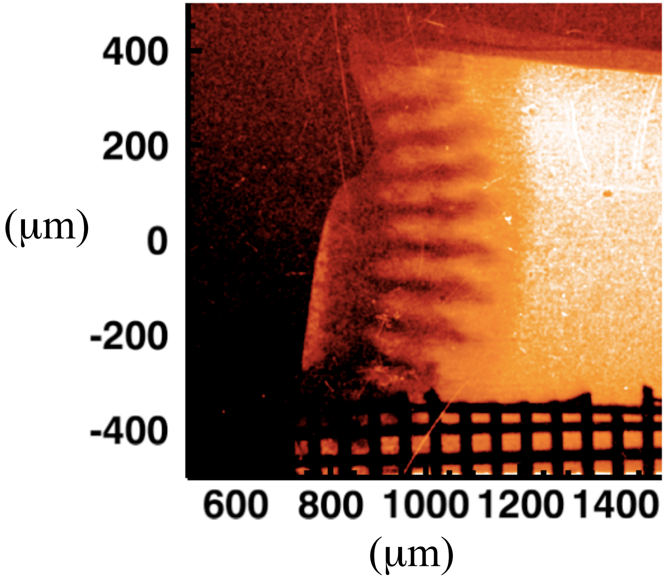


experiment sketch

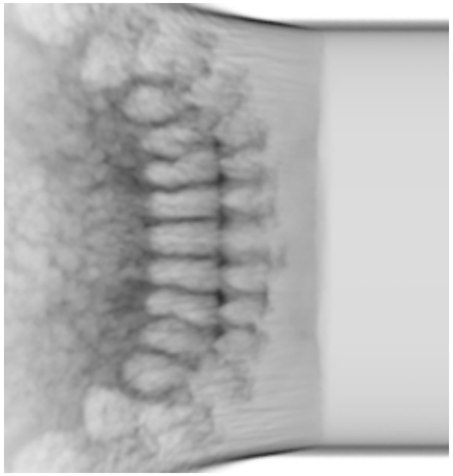


radiograph

There are discrepancies between experimental and simulated radiographs



Experimental radiograph



3-D Flash simulation

Discrepancies include:

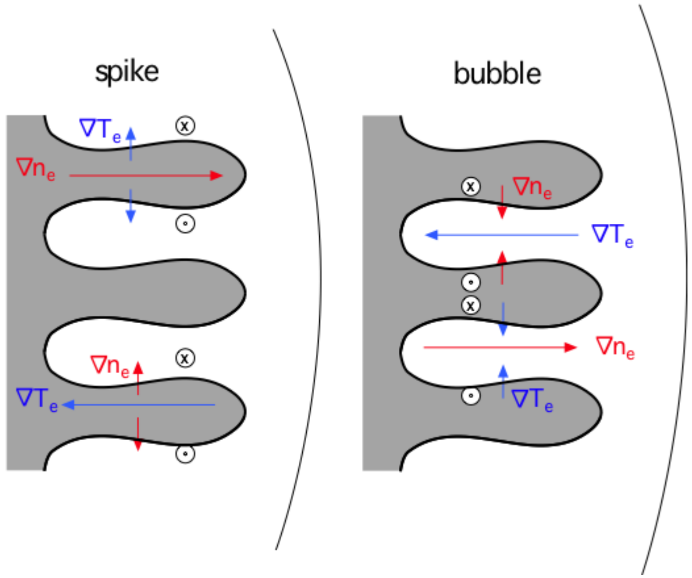
- Spike profile uniformity
- KH features

Interface structure can self-generate magnetic fields

Quasineutrality requires a balancing electromagnetic force with a sustained hydrodynamic force

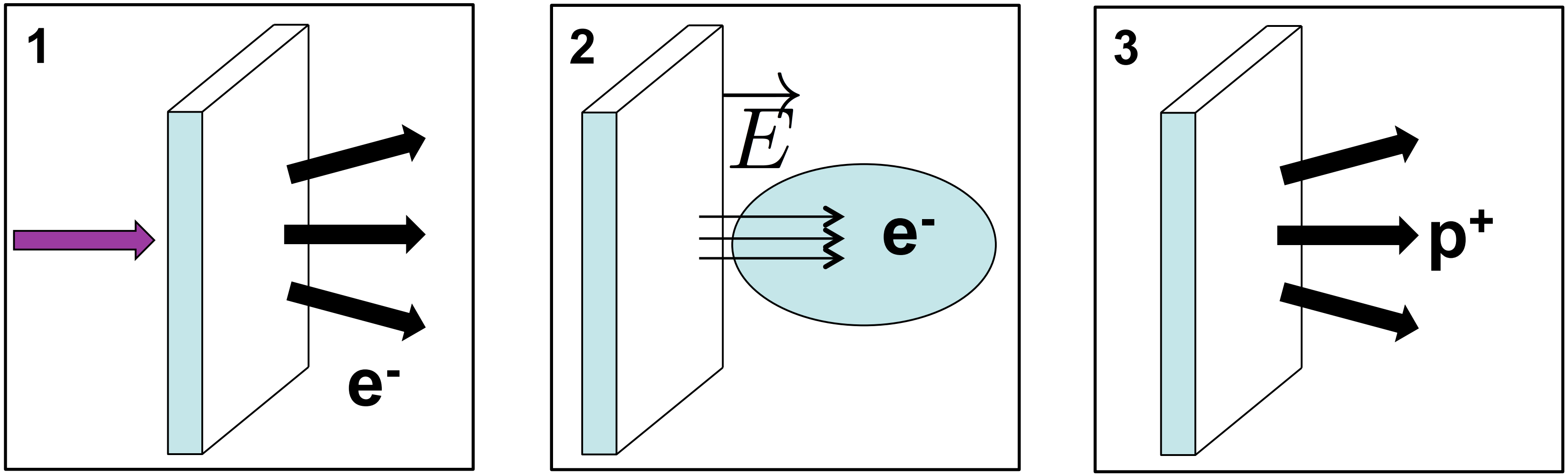
$$\nabla p_e = n_e(q\mathbf{E})$$
$$\frac{1}{c}\frac{\partial \mathbf{B}}{\partial t} = -\nabla \times \mathbf{E}$$

$$\Rightarrow \frac{\partial \mathbf{B}}{\partial t} = \frac{ck_B}{e}\left[\nabla T_e \times \nabla(\log n_e)\right]$$



Crude estimates put an upper limit of B~100 T!

Magnetic fields can be detected using proton radiography

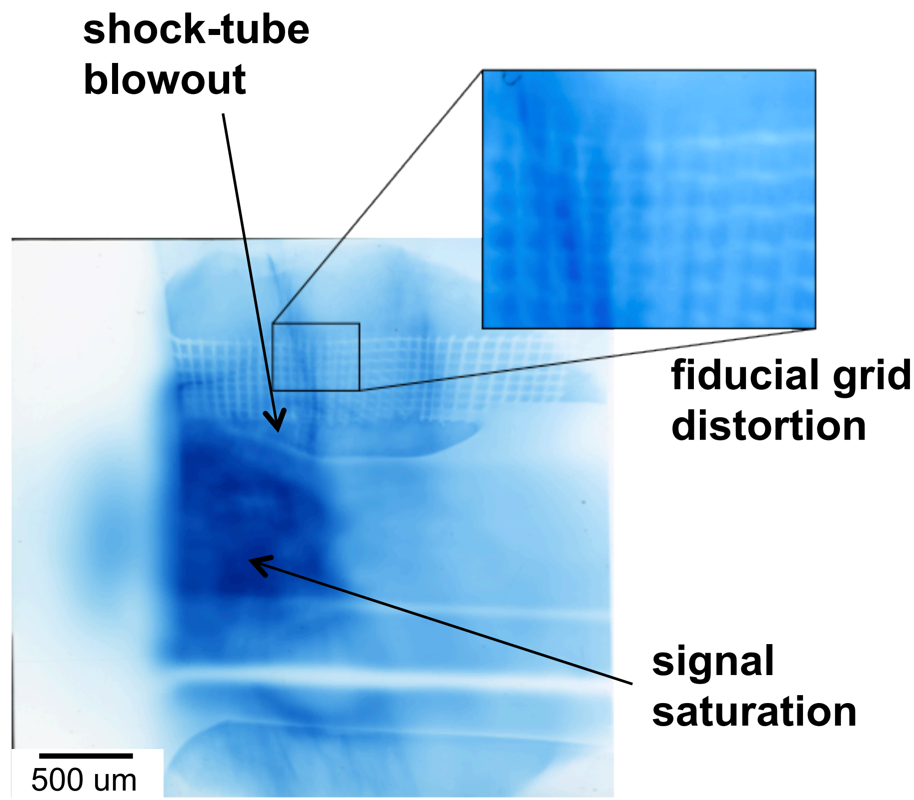


1. Laser irradiates foil, ejects electrons from foil rear.
2. Electron cloud generates electric field.
3. Protons are accelerated from foil
4. Protons are deflected in the presence of a magnetic field

Data shows distortions due to plasma interaction with proton source

Shock tube evolution indicates experiment progresses as expected.

Proton signal degradation obscures physics, and is associated with diffusion of plasma in laser chamber over time.



shot 9464, 18.3 MeV film

Summary

- **Self-generated magnetic fields may explain mysteries in previous data**
- **Applied proton diagnostic to the system**
- **We have identified sources of problems with the diagnostic, and this suggests ways to adapt the experiment to correct them.**

Collaborators and acknowledgments

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