Results of a supersonic, single-mode, shockwave-driven Kelvin-Helmholtz instability experiment

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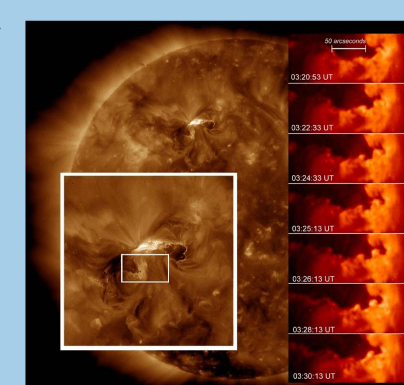
Motivation

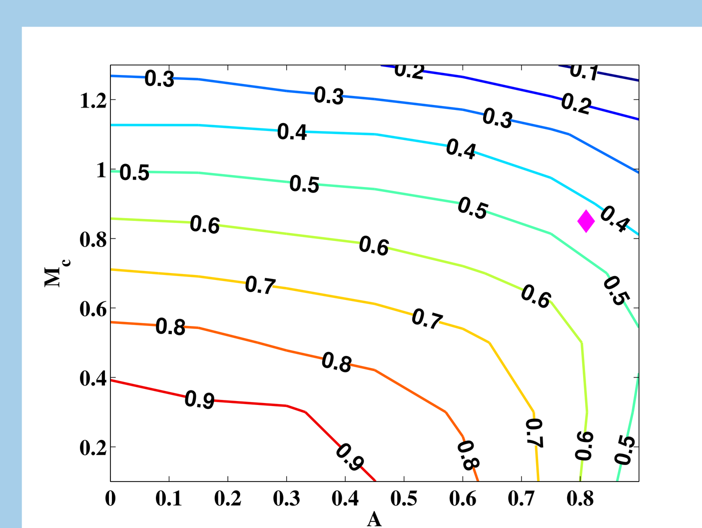
- The Kelvin-Helmholtz instability is one of the most common hydrodynamic instabilities, and is prominent in astrophysics and fusion.

The Kelvin-Helmholtz instability is commonly observed between cloud layers in gas giants, and among the convective processes of the sun.

Left: NASA, Voyager 1 (1979)
Right: NASA/SDO/Astrophysical Journal Letters



- A high convective Mach number inhibits the growth of the KH instability and, in the limit of M → √2, shuts down growth entirely.

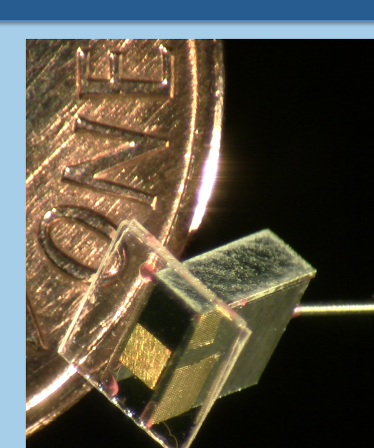


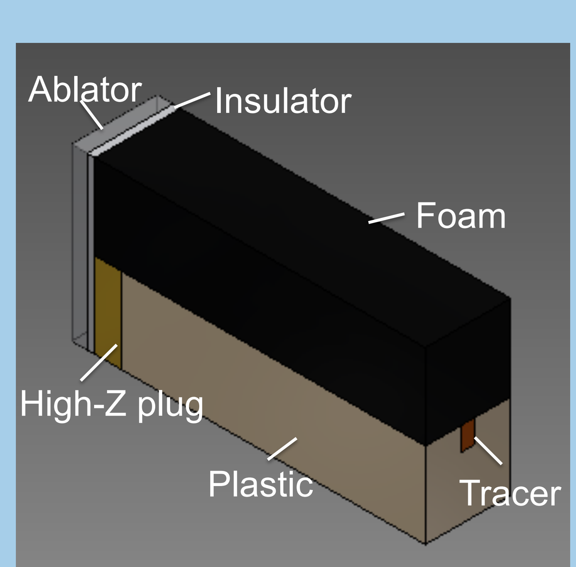
$$\gamma = \frac{k(\Delta u)}{2}\sqrt{1-A^2}\left(\frac{\sqrt{-1-M^2+\sqrt{1+4M^2}}}{M}\right)$$

.S.R. Choudhury et. al., Journal of Mathematical Analysis and Application. **214**, 561-586 (1997).
G. Malamud et al., High Energy Density Physics. **9**, 4 (2013)

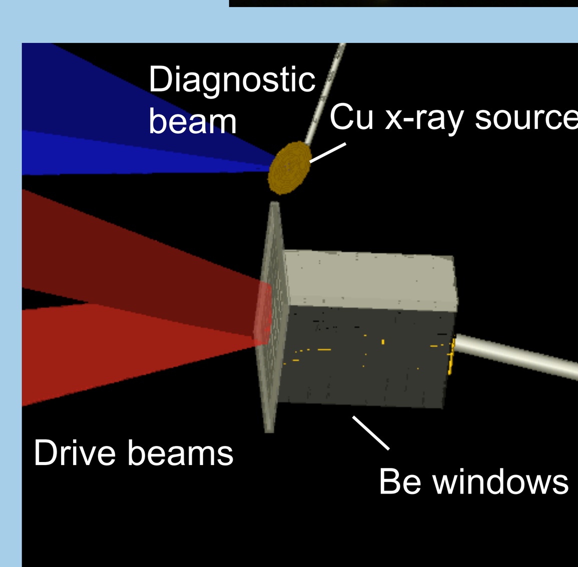
Shock-wave driven laser hydro experiments

- A 20 to 30 ns pulse drives the system with a steady shockwave, creating shear flow between a low density foam and a high density plastic.





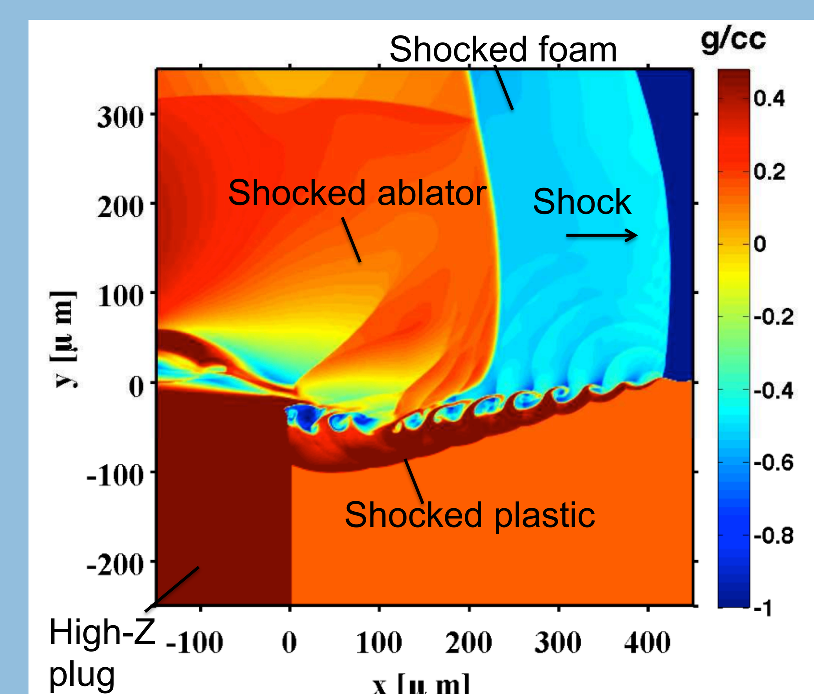
Physics package



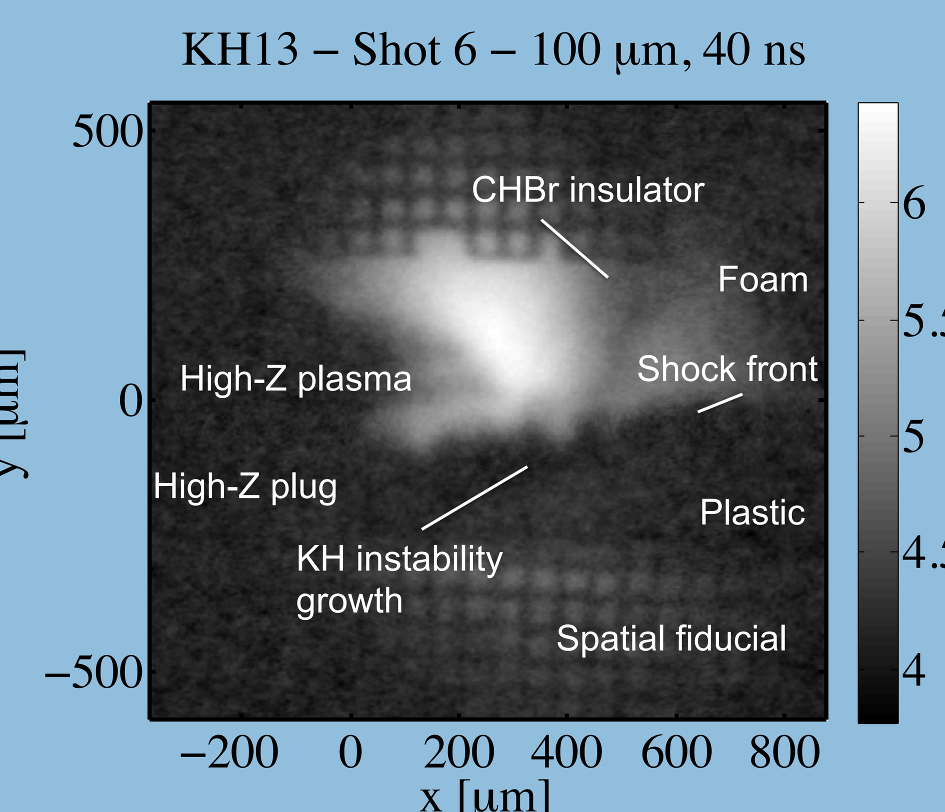
Chamber view

August 2013 results

- In our first campaign, Kelvin-Helmholtz growth may have been limited by a higher than anticipated compression of our foam, resulting in a smaller instability relevant region.



DAFNA 2D simulation
40 ns, log(ρ)

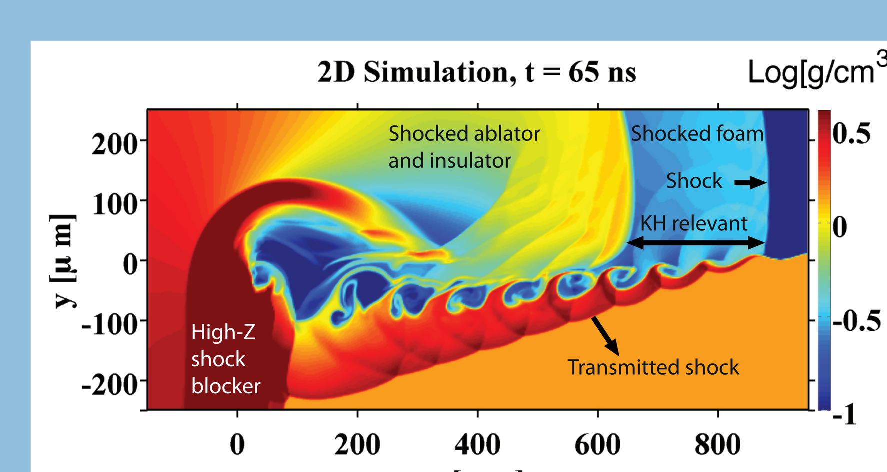


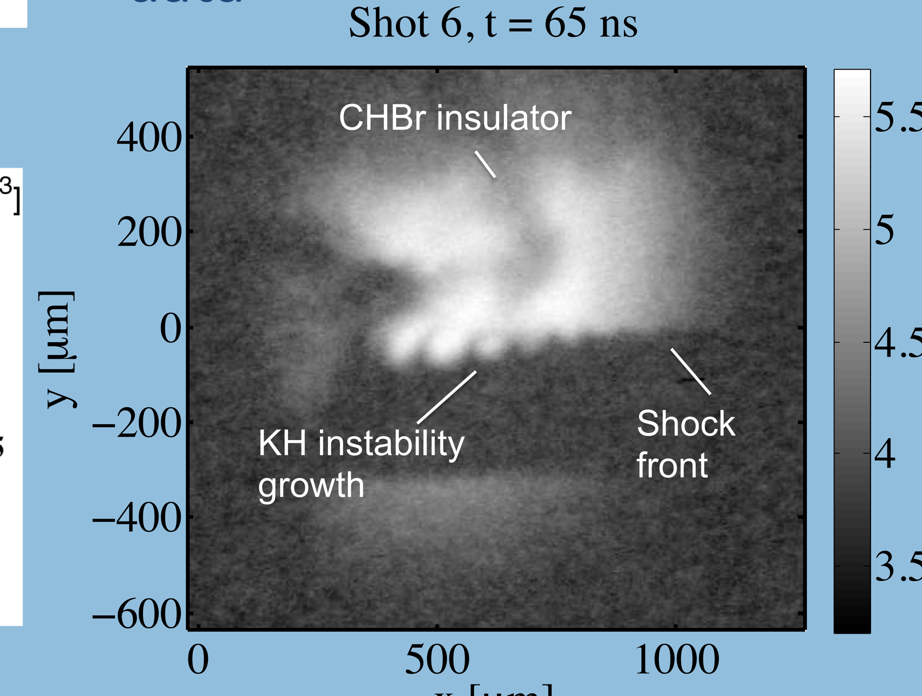
100 µm wavelength
40 ns

January 2014 results

- By increasing our drive from 20 ns to 30 ns, we were able to extend the duration of our steady-drive conditions and look later in time.
- At late times, we were able to observe Kelvin-Helmholtz structure.
- **Top left**: Table of predicted and measured values.
- **Bottom left**: Revised 2D simulation
- **Bottom right:** Experimental data

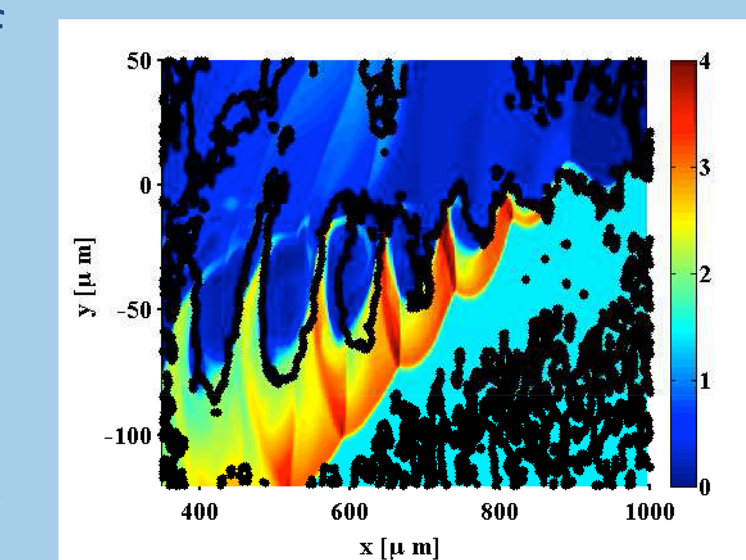
Parameter	Experiment	Simulation
Shock velocity u_s (μm/ns)	28 ± 2	29
Deflection angle (°)	8 ± 2	8.3
Compression	5.0 ± 1.5	4
Shocked foam pressure (Mbar)	0.63 ± 0.08	0.59
Shear velocity Δu (μm/ns)	20 ± 3	20
Rollup spacing λ (μm)	77 ± 6	80

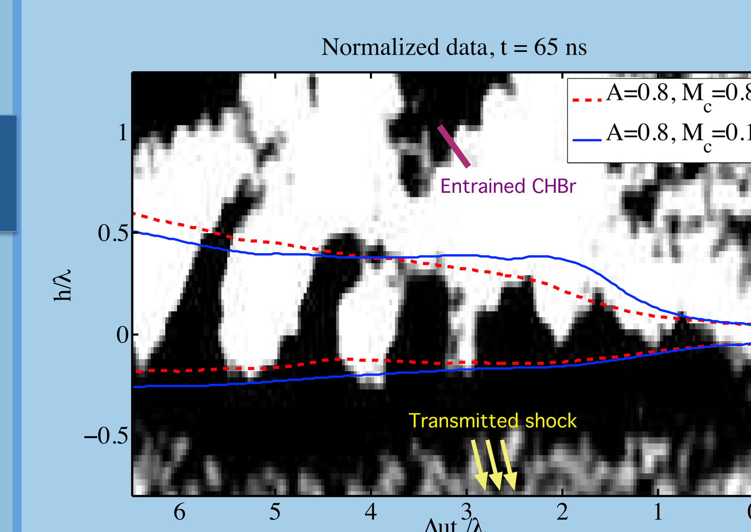


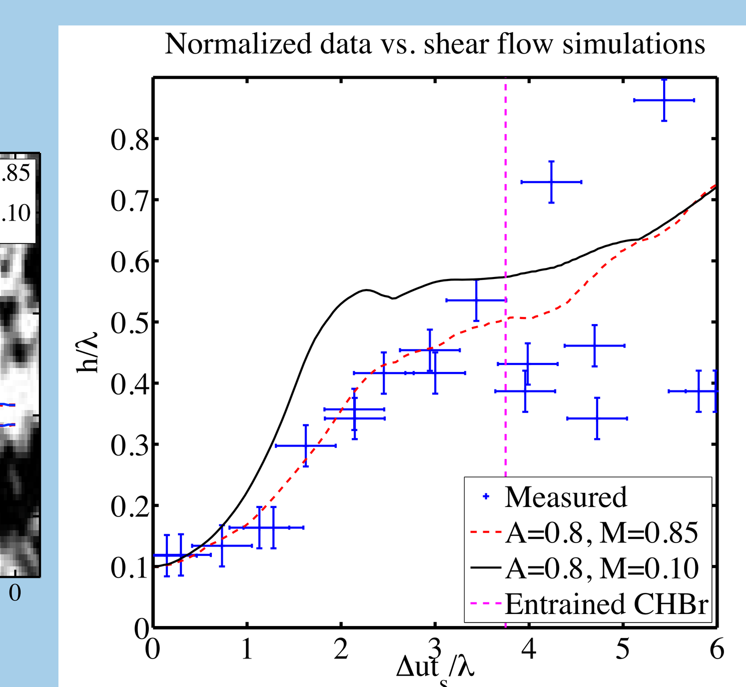


Analysis

- The growth rate of the modulations is in good agreement with simulations, until they are disturbed by entrained material from the ablation surface.
- **Top right**: Contour of experimental data plotted over a full 2D simulation.
- **Bottom**: Comparison to pure shear flow simulation, at high and low convective Mach numbers.







Conclusions

This data is the first lab observation of single-mode, Kelvin-Helmholtz instability evolution in a supersonic flow.

Funding acknowledgements

This work is funded by the U.S. Department of Energy, through the NNSA-DS and SC-OFES Joint Program in High-Energy-Density Laboratory Plasmas, grant number DE-NA0001840, and the National Laser User Facility Program, grant number DE-NA0000850, and through the Laboratory for Laser Energetics, University of Rochester by the NNSA/OICF under Cooperative Agreement No. DE-FC52-08NA28302.