Supersonic, single-mode, shockwave-driven Kelvin-Helmholtz Instability Experiment on OMEGA-EP

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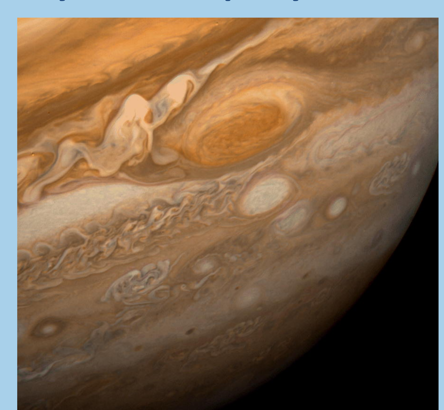
Motivation

- The Kelvin-Helmholtz instability causes mixing in systems with shear flow. It is one of the most common hydrodynamic instabilities, and is seen in many astrophysical systems.



Gas planets such as Jupiter are subject to Kelvin-Helmholtz instability growth between cloud bands and within storms.

Photocredit: NASA, Voyager 1 (1979)

- A high convective Mach number (roughly half the lab-frame flow Mach number) suppresses Kelvin-Helmholtz instability growth and, if sufficiently high, prevents growth entirely.

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

As the convective Mach number (M) approaches zero, we obtain our classic Kelvin-Helmholtz (KH) growth rate. As M approaches √2, the growth rate approaches zero, and KH instability growth is suppressed.

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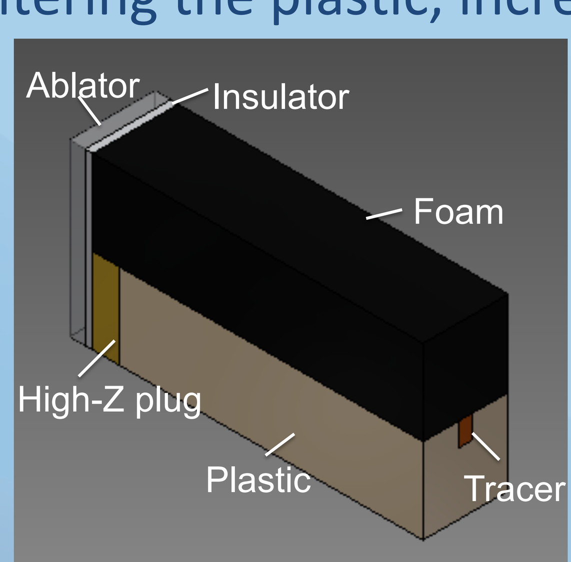
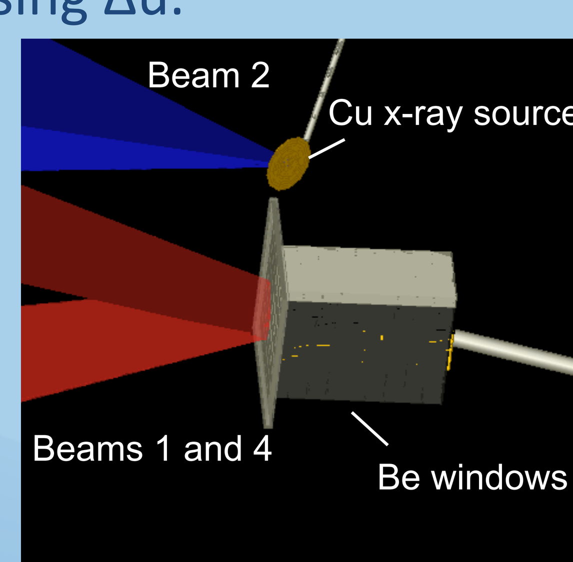
- This experiment will be performed in a compressible regime with well-characterized, deliberately seeded initial modulations.

Experimental design

- A stitched 20 ns pulse drives the system with a steady shock wave instead of a decaying blast wave.
- The shockwave causes shear between a low density foam and high density plastic.
- A high-Z plug prevents the shock from directly entering the plastic, increasing Δu.



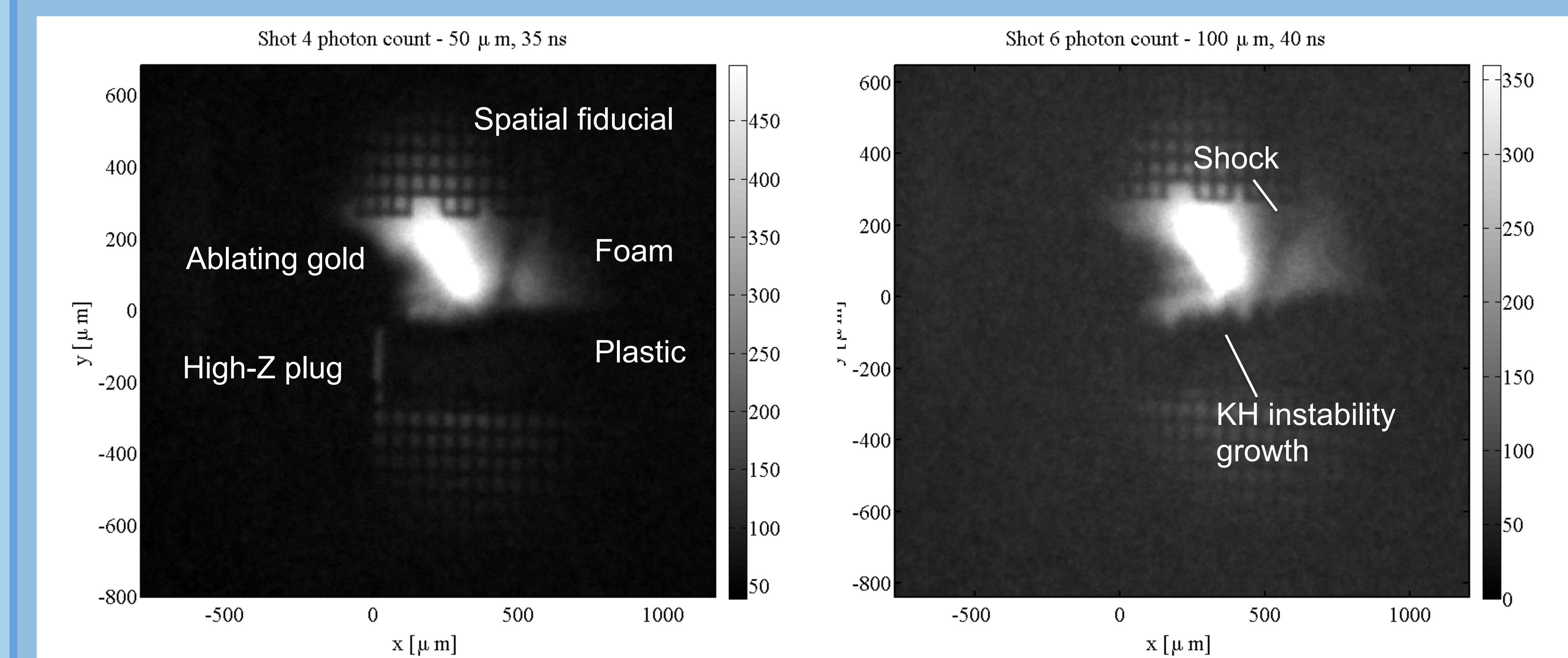
Physics package



Chamber view

Experimental results

- The primary diagnostic was Spherical Crystal Imaging (SCI), a variant of x-ray radiography.
- We studied the evolution of the system at 35 and 40 ns.
- We studied the case of natural surface roughness, and of seeded perturbations at 50 µm and 100 µm wavelengths.



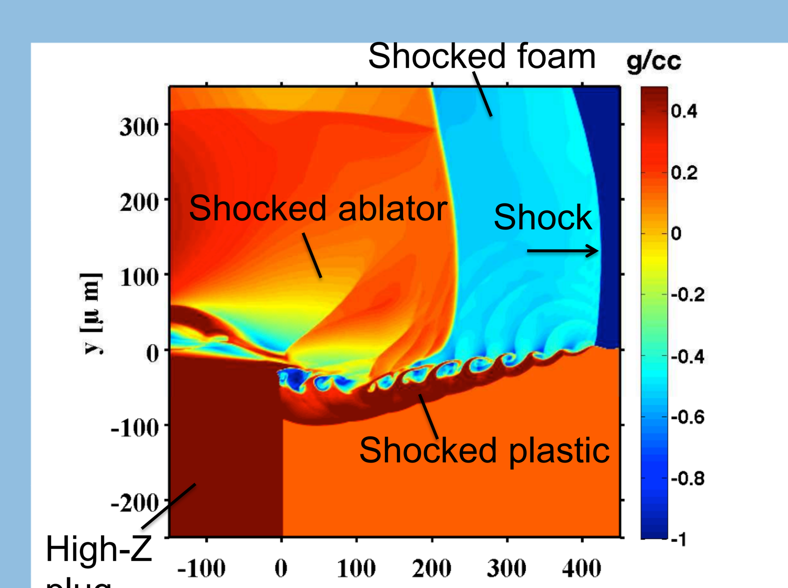
50 µm wavelength
35 ns

100 µm wavelength
40 ns

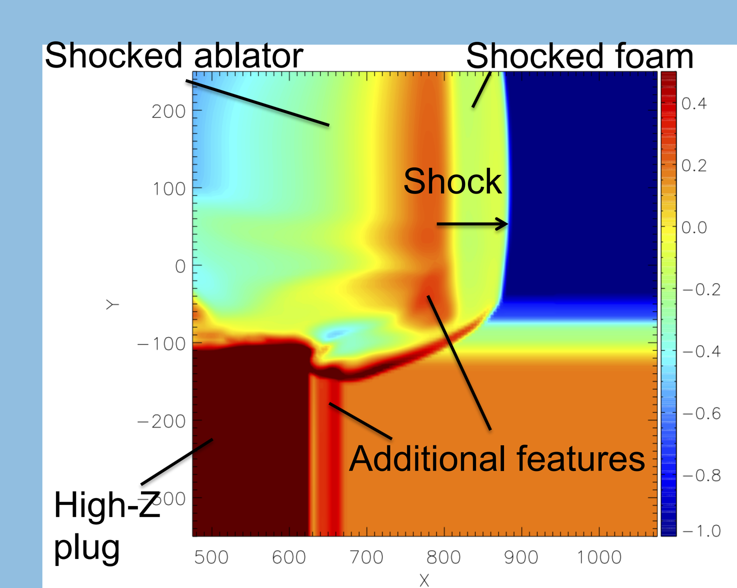
- Although the system generally evolved as predicted, growth of the 50 µm perturbation is not immediately discernable.
- The instability growth lacks the distinct, curled structure of a Kelvin-Helmholtz rollup. It is currently unknown whether this is an issue with resolution, an indicator of experimental complications, or an effect of high Mach number compressibility.

Simulations

- Additional structure is seen in our radiation hydrodynamics code (CRASH, UMich) that is not visible in our pure hydrodynamic simulations (DAFNA, NRC). The CRASH results seem to match better with observations.
- Velocity is generally higher in the experiment



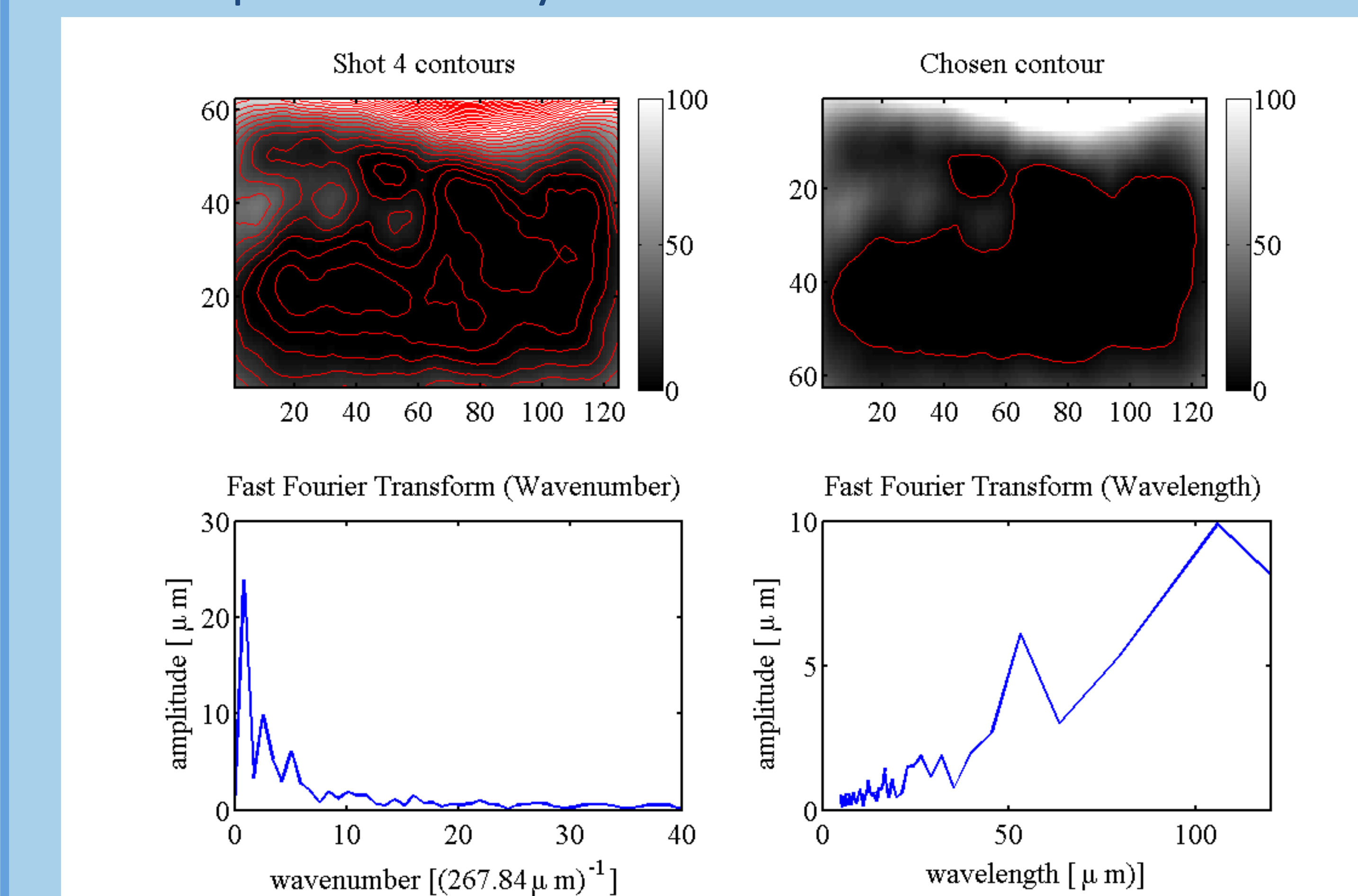
DAFNA
40 ns, log(ρ)



CRASH
40 ns, log(ρ)

Preliminary analysis

- Structure along the interface can be detected computationally, even if it is not immediately visible. Pictured below, a Fast Fourier Transform reveals the existence of instability growth at 50 µm.
- A sharp spatial gradient in the detector's signal has complicated analysis.



- Top left: We fit contours of equal signal to our data, approximating them as contours of equal density.
- Top right: We select the contour that best fits the interface
- Bottom left and right: A Fast Fourier Transform (FFT) shows two distinct wavelengths that rise above the noise. The 50 µm wavelength corresponds to the seeded perturbation, and the 100 µm wavelength is likely due to an obscured transition between rollups.

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