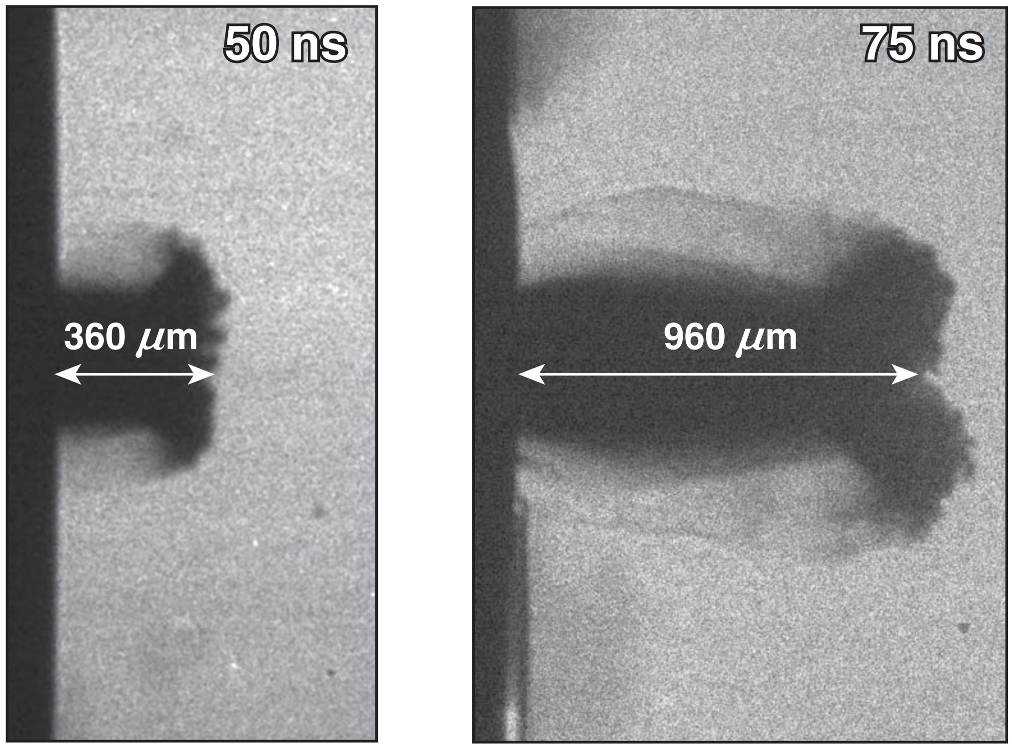
Temporal Evolution of Directly Driven Hydrodynamic Jets Relevant to Astrophysics



Two different shots with the same target design

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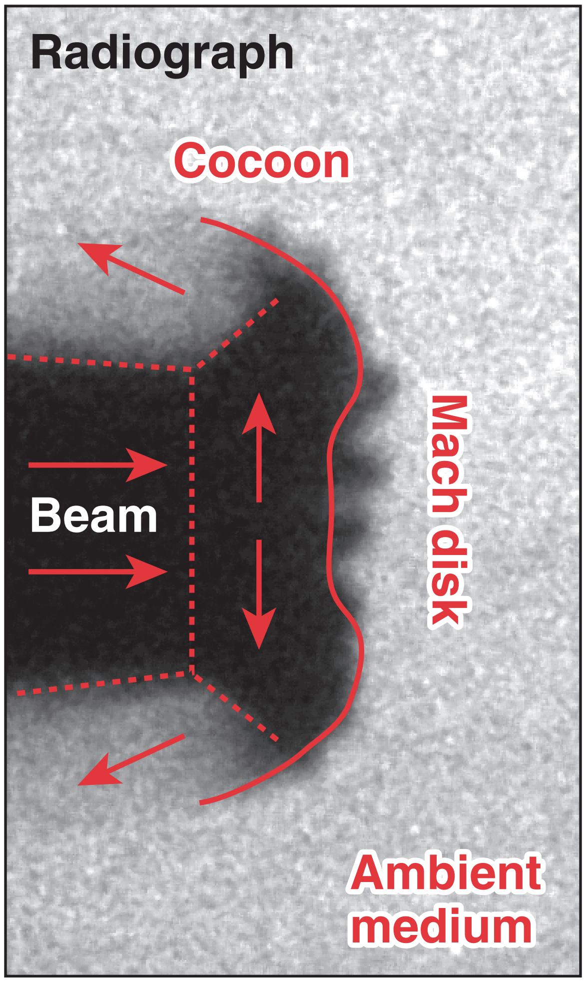
Summary

Directly driven plasma jets hydrodynamically resemble astronomical jets

UR LLE

- A hydrodynamic jet was formed with a strong laser shock driving material from a titanium plug into a low-density-foam ambient medium.
- Temporal evolution of shock surfaces were tracked at several times.
- Simulations reproduce the global features.
- The mass of the jet was determined, giving a jet-to-ambient density ratio of 1 and a Mach number of 3.

A basic jet schematic shows some features tracked in experiments and models



Beam: the bulk of the inner, forward moving flow

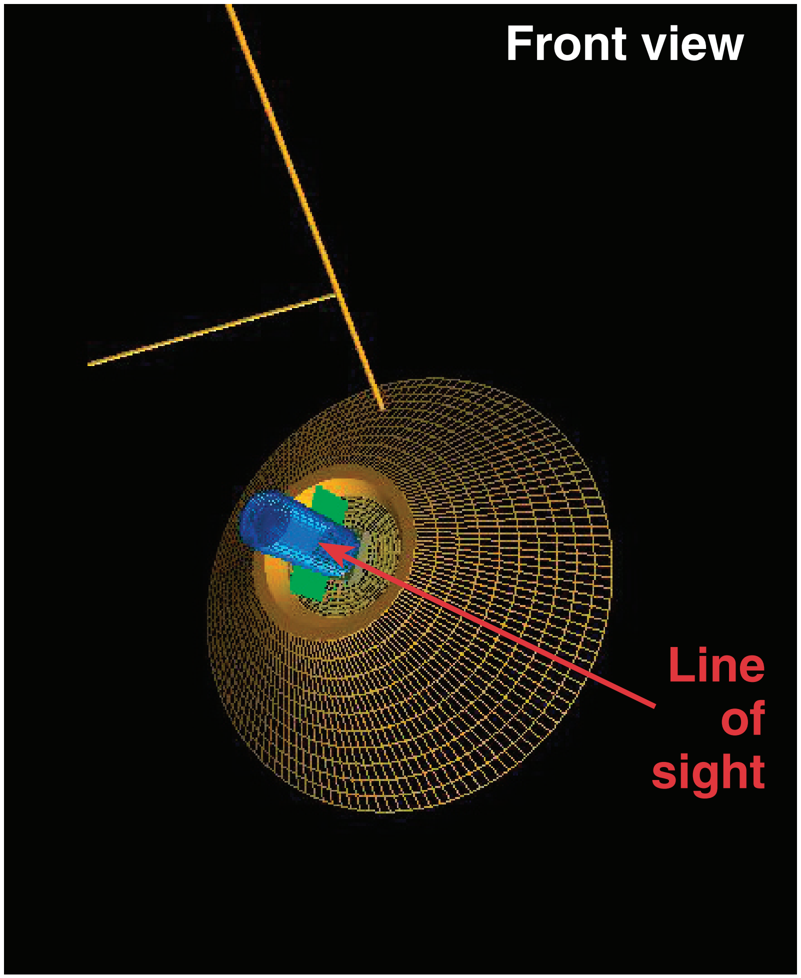
Mach disk: inner shock that slows the jet material

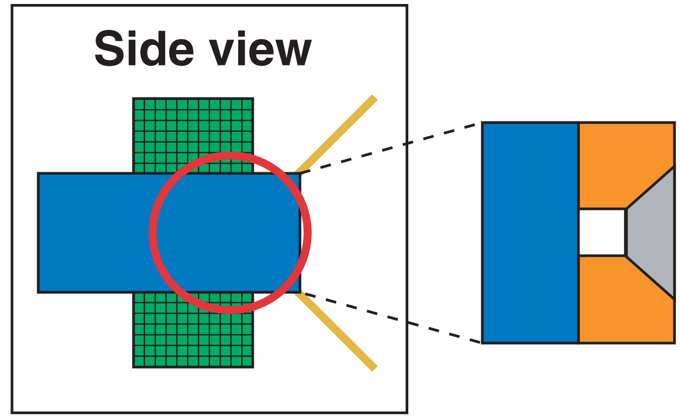
Cocoon: low-density region of post-shock gas evacuated by an outward moving bow shock (to which this radiographing source is not sensitive)

Ambient medium: the environment in which the jet evolves

TC7251

The target is designed to minimize background





- Laser beams drive a jet from behind a cone into foam.
- The jet evolves in a region between calibration grids.
- The target is backlit from 180° opposite the detector.
- The shield cone minimizes background on the detector.

2-mm diameter, 4-mm length
20-mm diameter, 5-mm depth

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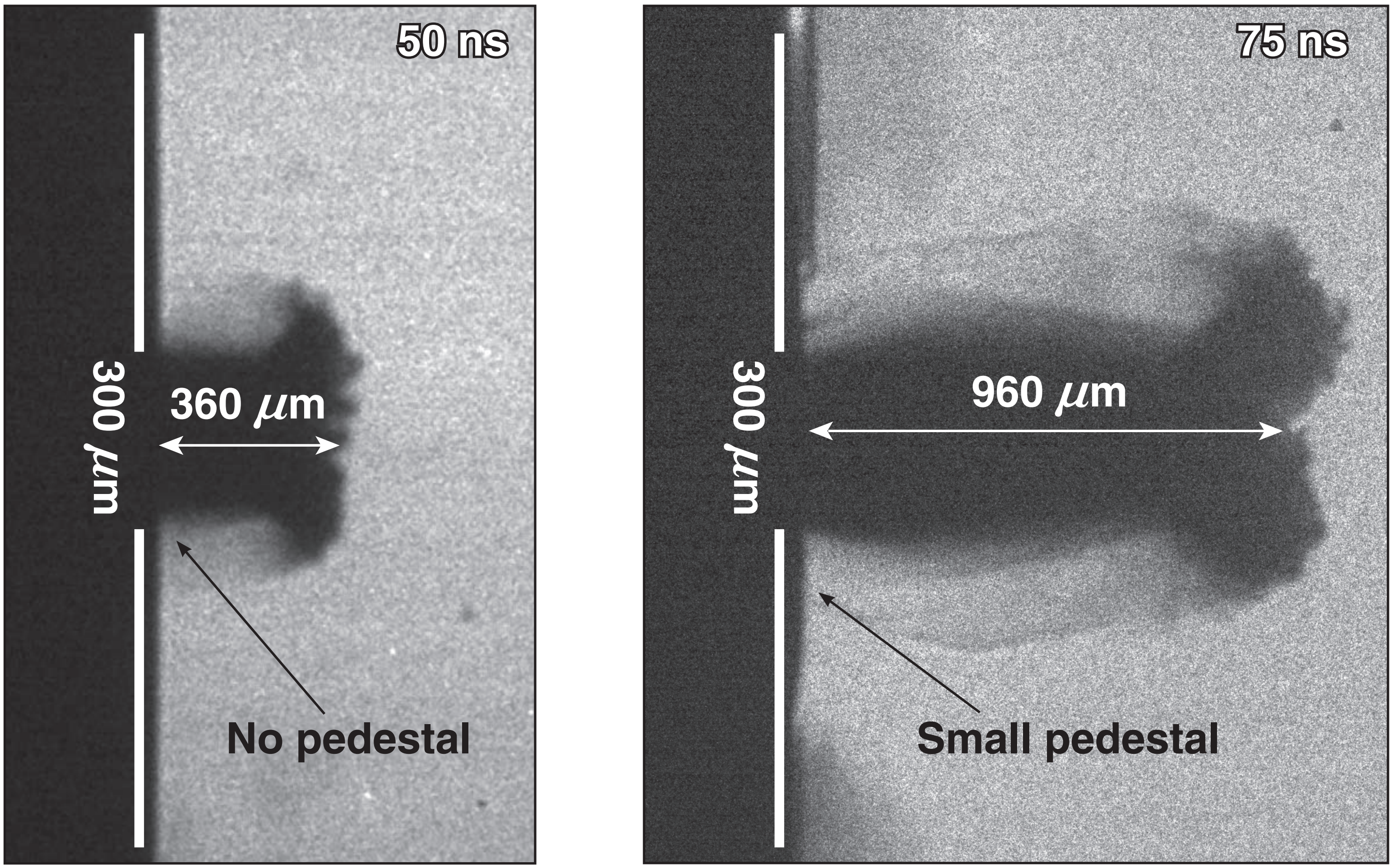
Images at 50 and 75 ns give an average velocity of 24 μm/ns



50- and 75-ns jet masses were calculated to be 2.3 and 6.2 μg respectively

$$m_{Ti} = -\Sigma_{pixels} \ln(I_{pixel}/I_o)/\mu_{Ti}$$

- m_{Ti} is the total mass of the Ti jet
- I_o is the intensity in a region of unshocked foam
- μ_{Ti} is the Ti mass absorption for 5.18 keV (the radiography x-ray source, vanadium)

These masses give an average jet density of ~100 mg/cc.

The unshocked foam has a density of 100 mg/cc.

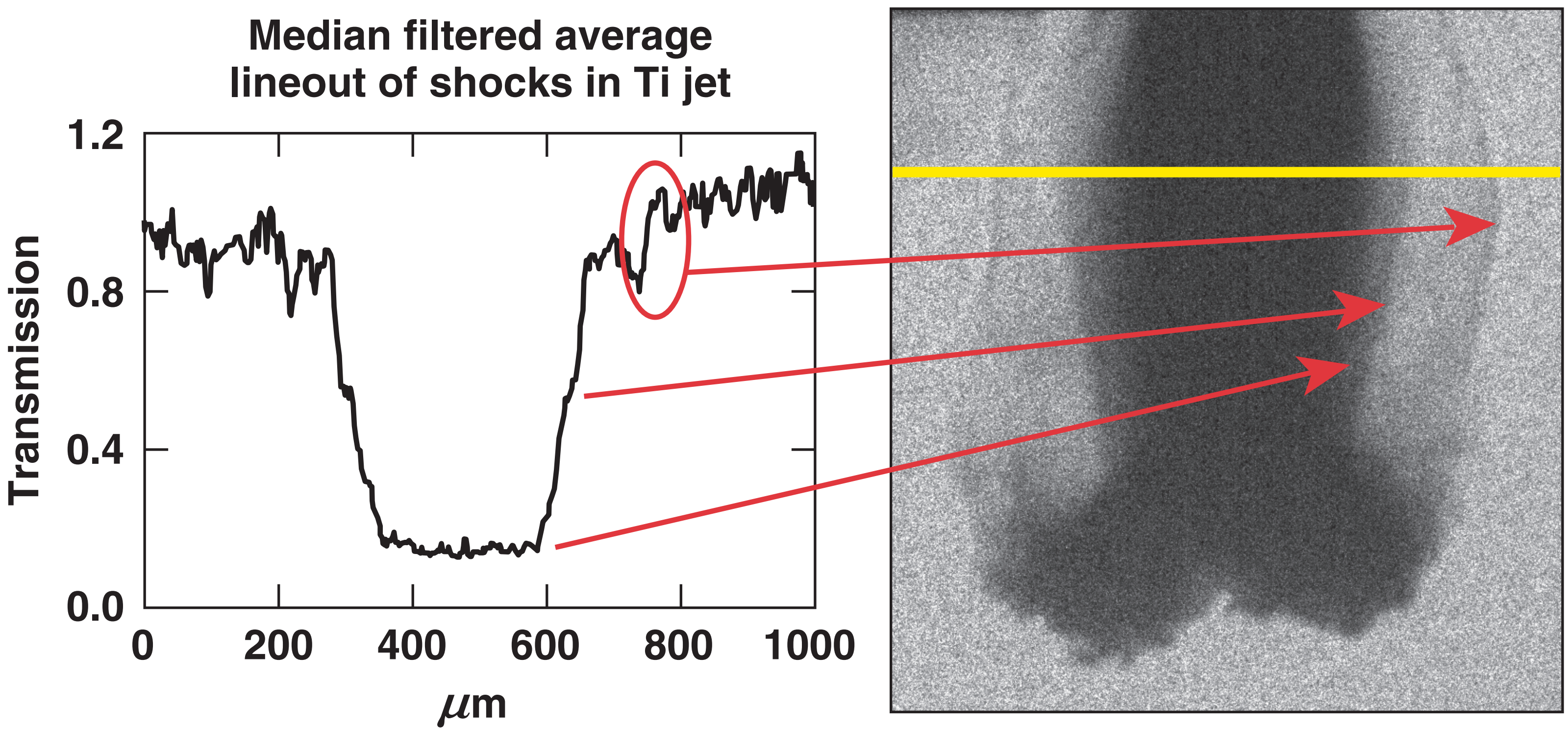
The density ratio of the Ti jet to unshocked foam is ~1.

The jets are hydrodynamically similar to astrophysical jets

Dimensionless parameters	OMEGA experiments	Young stellar objects	Planetary nebulae
Jet density	10^{21}/cc	10^{8}/cc	10^{6}/cc
Ambient density	10^{21}/cc	10^{7} to 10^{9}/cc	Varied
Density ratio	~1	0.1 to 10	Varied
Jet velocity (km/s)	24	10 to 100	100 to 1000
Sound speed	3	100 to 1000	~100
Mach number	3	10 to 20	1 to 10

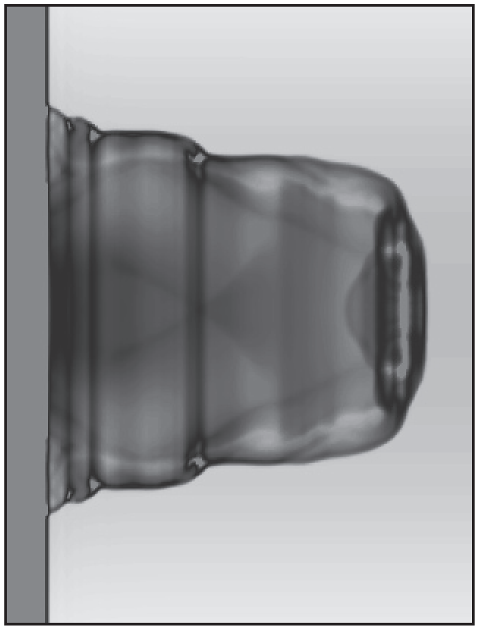
- Experimental jet-to-ambient density ratios are in the same range as stellar jets, and Mach numbers are at the low end of the relevant ranges.

Phase contrast of backlighter x-rays enhances the shock surfaces

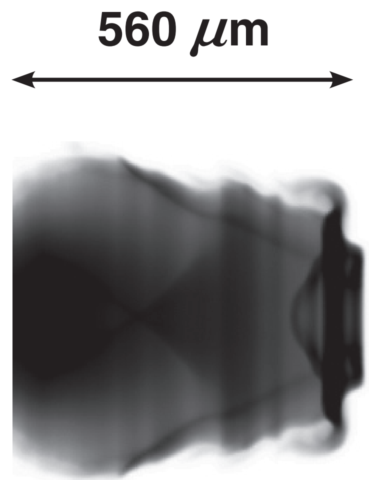


- Yellow line indicates where lineout was taken. Red arrows help identify several prominent shock features. The red circle indicates a shock surface exhibiting phase contrast.

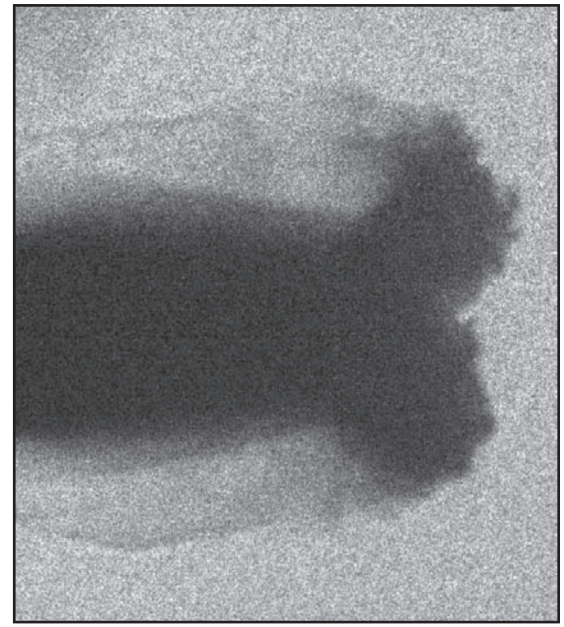
Simulations reproduce the global features



Total column density



Titanium
column density



Experiment

- There is qualitative agreement between a 2-D *DRACO* simulation and the experiment in post-recollimation jet features.
- All images are shown for 75 ns.
- The jets evolves more slowly in the simulation.

Summary/Conclusions

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