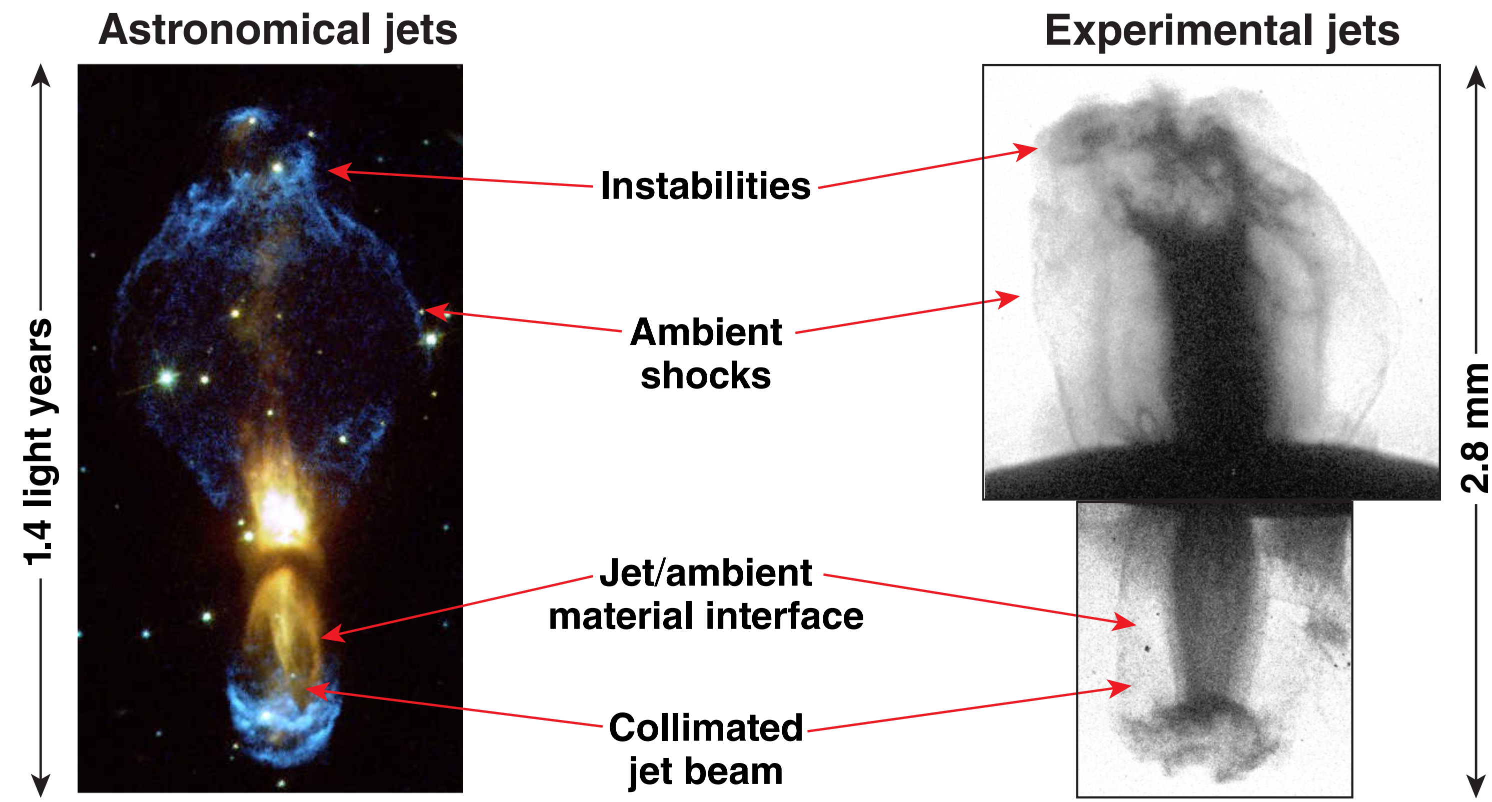
OMEGA Laser-Driven Hydrodynamic Jet Experiments with Relevance to Astrophysics



S. Sublett, J. P. Knauer,
D. D. Meyerhofer, and A. Frank
University of Rochester
Laboratory for Laser Energetics

49th Annual Meeting of the
American Physical Society
Division of Plasma Physics
Orlando, FL
12–16 November 2007

Summary

Features of the *laboratory* jets are consistent with an adiabatic *astrophysical* jet model

UR LLE

- As predicted by an adiabatic astrophysical model,* experimental bow-shock morphology is constant in time and independent of input energy.
- Dimensionless scaling parameters place OMEGA jets in the stellar jet regime.
- Distinctions between double-pulsed jets and single-pulsed jets have been observed for the first time.

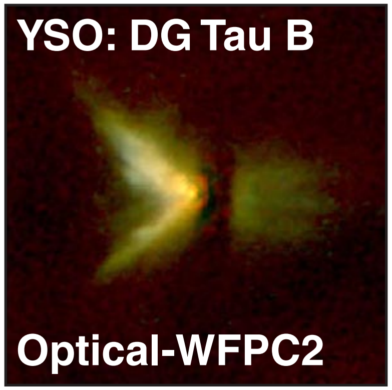
E16230

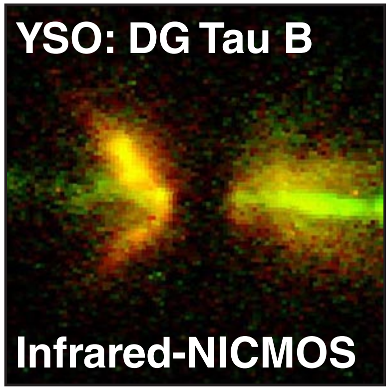
*E. C. Ostriker *et al*., Astrophys. J. 557, 443 (2001).

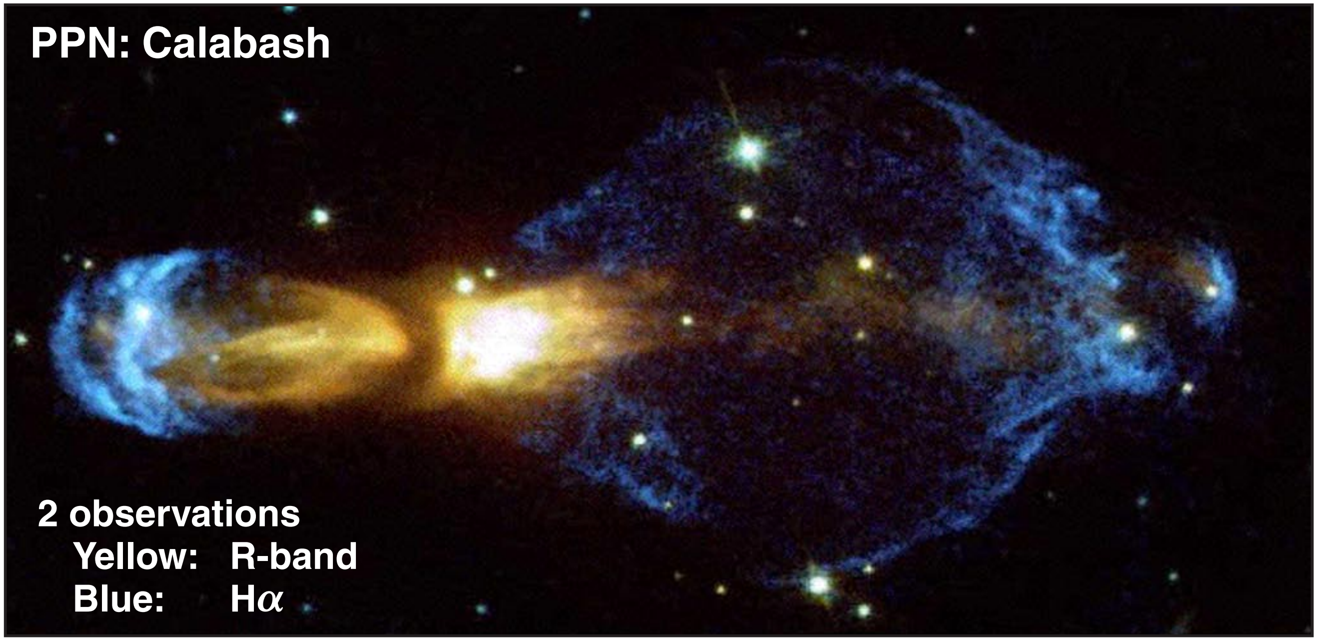
Motivation

Experiments detect features not routinely observed in astrophysical jets

UR LLE



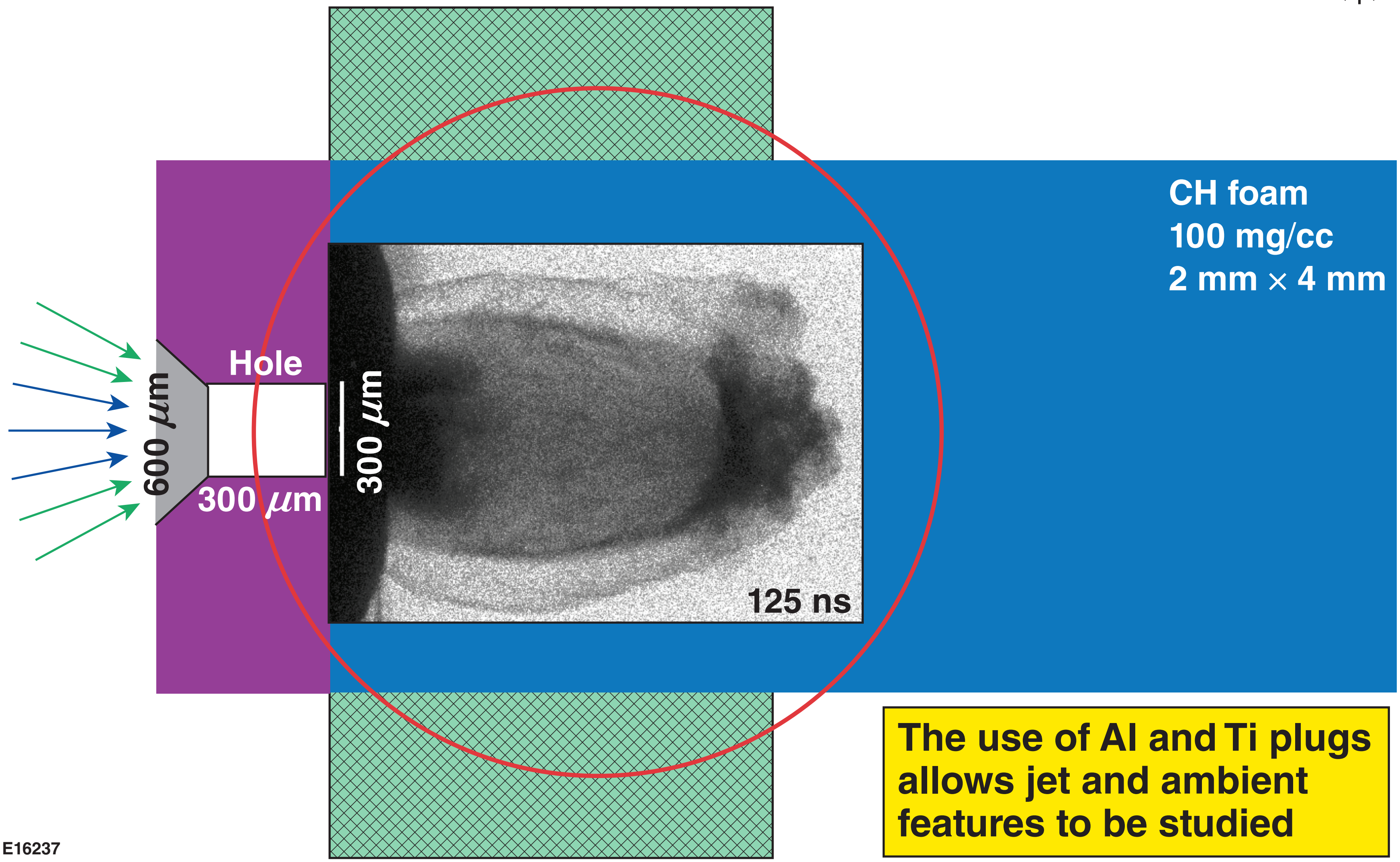




- Experimental jets are imaged with multiple wavelengths that can detect both the jet and ambient shocks.
- OMEGA jets are viewed at the source; Astrophysical jet sources are obscured.

E16231

An OMEGA jet is formed by releasing material off a mid-Z (Al or Ti) plug embedded in a high-Z tungsten washer



The use of Al and Ti plugs allows jet and ambient features to be studied

E16237

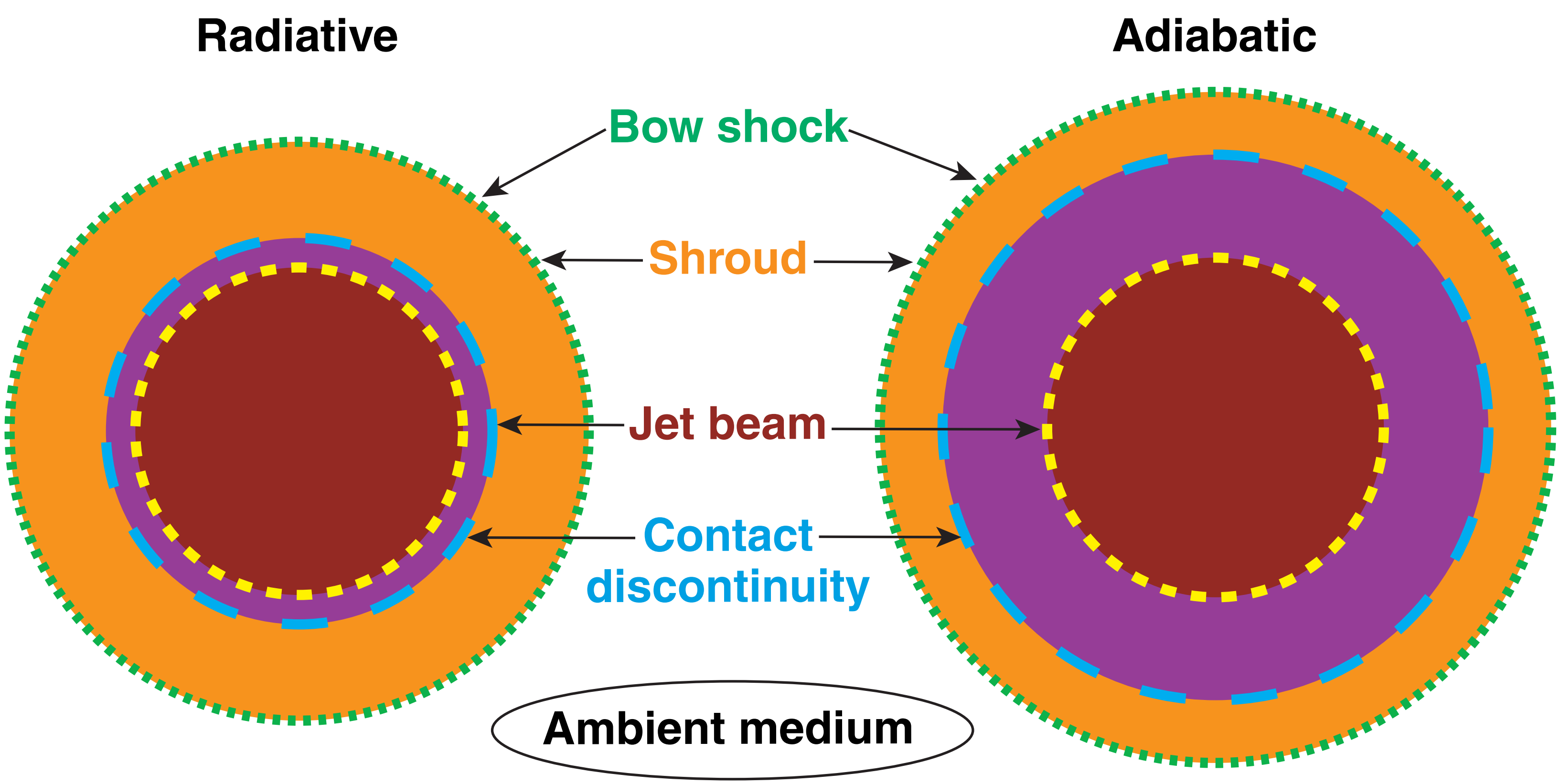
Dimensionless parameters place OMEGA jets in the stellar regime

Dimensionless Parameters	OMEGA Experiments	Young Stellar Objects	Planetary Nebulae
Density contrast: Jet/ambient density	5 to 20	1 to 20	~1000
Mach number: Ratio of V_s to C_a	2 to 4	10 to 40	40 to 100
Reynolds number: Inertial/viscous drag	~1000	~10^{13}	~10^{12}

- Density contrast > 1 places jets in the overdense regime.
- Mach number > 1 places jets in the supersonic regime.
- Reynolds number >> 1 places jets in the unstable regime.

E15245a

Jets are driven radially by two distinct methods

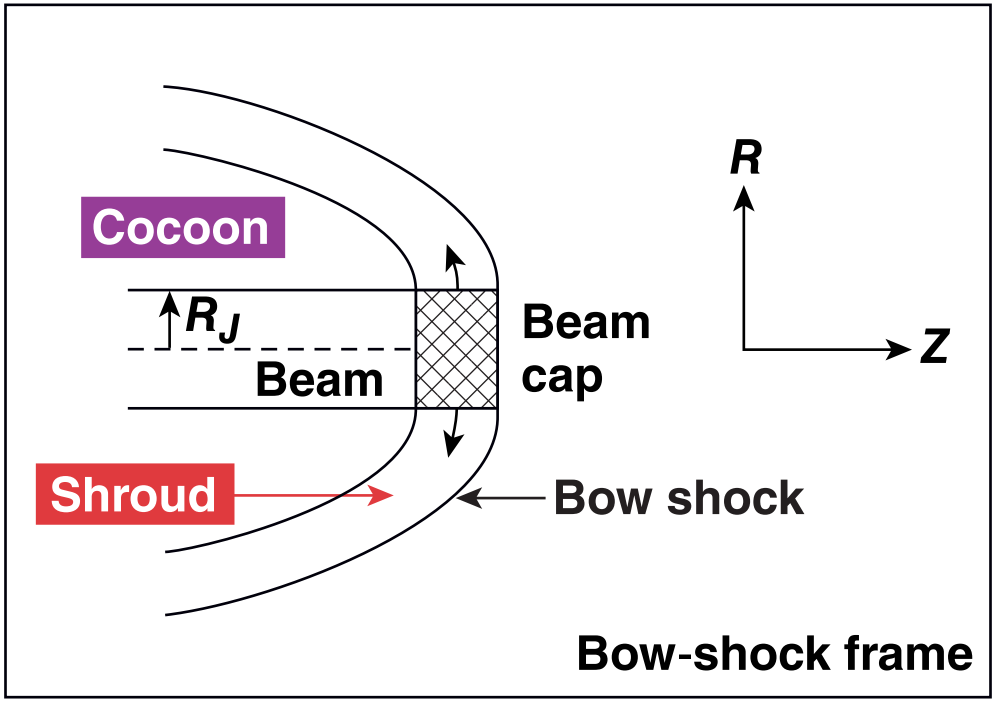


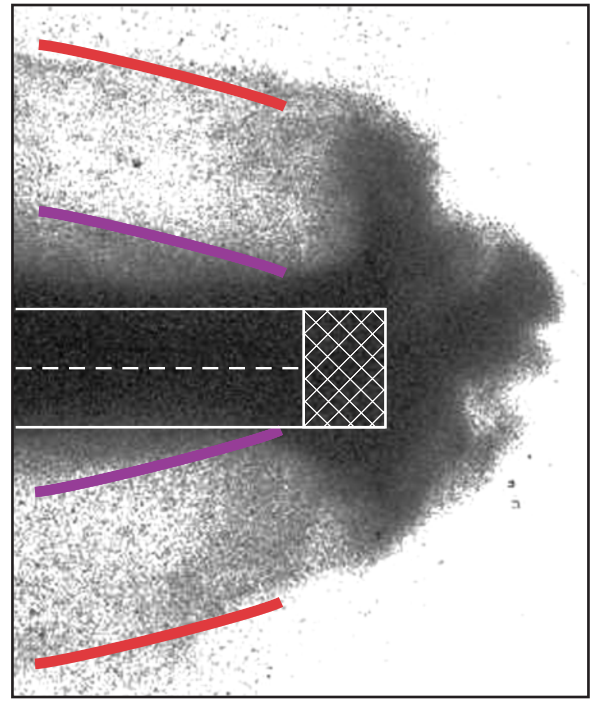
- The cocoon is able to cool, so it becomes thin and dense.
- Jet is driven radially by the ram pressure of the cocoon.

- Hot cocoon, unable to radiate, is more diffuse.
- Jet is driven radially by the thermal pressure of the cocoon.

E16235

An adiabatic jet model* predicts a bow-shock morphology





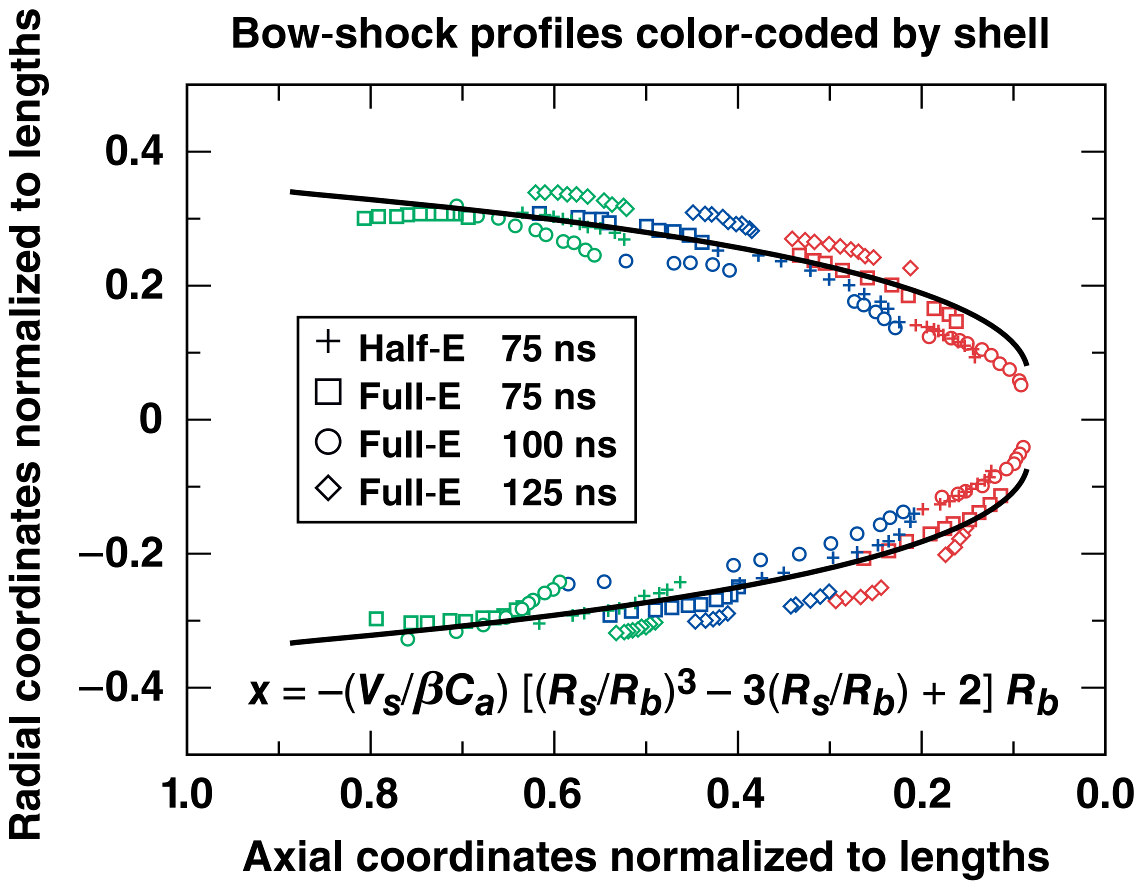
- The beam-cap energetics in this model account for the cocoon energy loss and, therefore, determine the ambient and jet densities, radii, and speeds.
- Experimental jet density, speed, and radius are determined from the radiographs.

E15243a

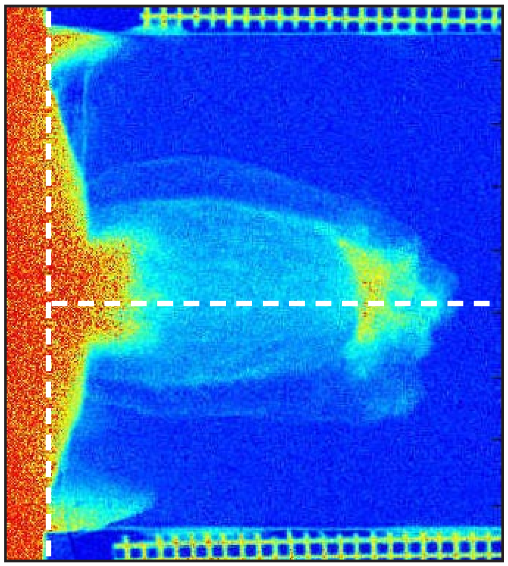
*E. C. Ostriker *et al.*, Astrophys. J. 557, 443 (2001).

An adiabatic *astrophysical* model is fit to *experimental* bow-shock profiles

Bow-shock profiles color-coded by shell

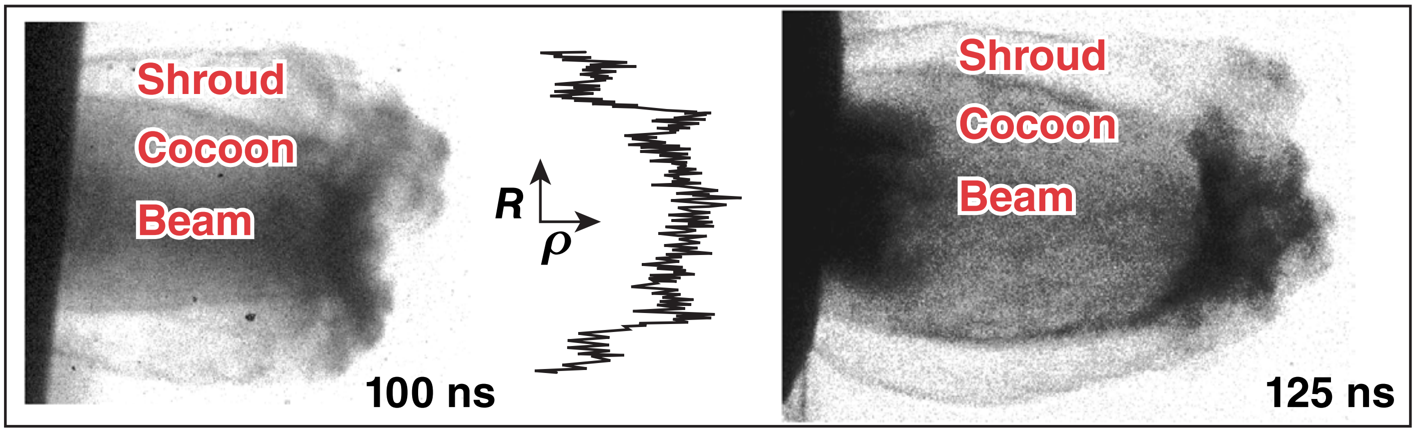


Both radial and axial bow-shock-profile coordinates were normalized to jet length.



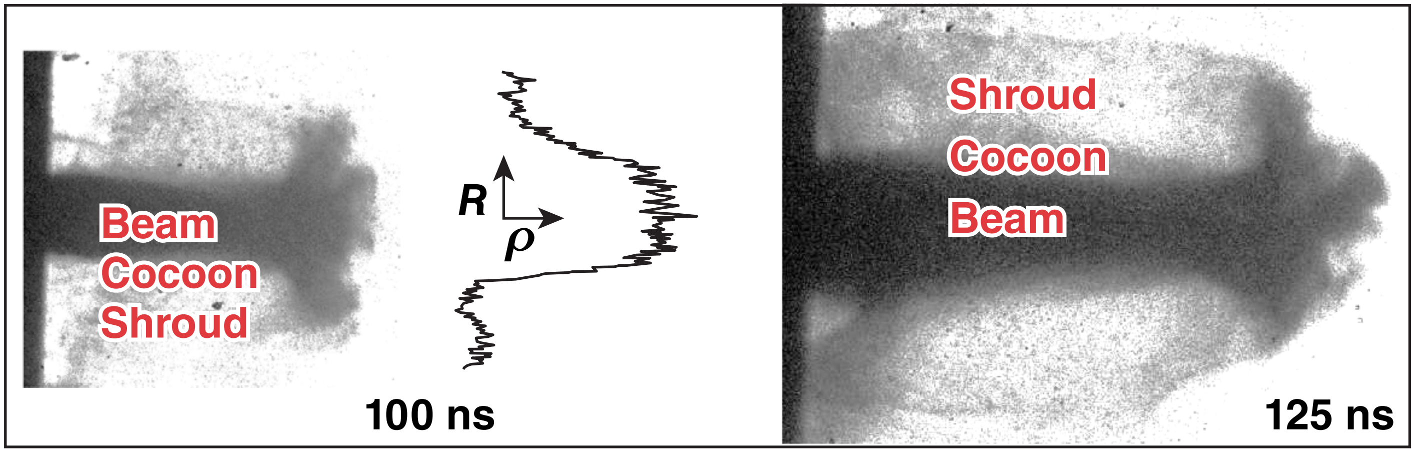
As predicted by the adiabatic astrophysical model, experimental bow-shock shape is constant in time and independent of input energy.

Single-pulsed jets are created by seven simultaneous laser beams



- The density along the jet beam shows a dense beam cap.
- The cocoon has a large radius.
- Cocoon density is nearly the same as the jet beam density.

Double-pulsed jets are created by three laser beams, followed 10 ns later by a second pulse of four laser beams



- The cocoon density is roughly the same as the shroud density and much less than the beam density.
- The cocoon radius is small compared with single-pulsed jets.
- Double-pulsed jets exhibit a more-uniform density along the jet beam rather than a secondary working surface.

The differences in single- and double-pulsed jets are apparent within ten pulse-separation periods.

Summary/Conclusions

Features of the *laboratory* jets are consistent with an adiabatic *astrophysical* jet model

- As predicted by an adiabatic astrophysical model,* experimental bow-shock morphology is constant in time and independent of input energy.
- Dimensionless scaling parameters place OMEGA jets in the stellar jet regime.
- Distinctions between double-pulsed jets and single-pulsed jets have been observed for the first time.

*E. C. Ostriker *et al*., Astrophys. J. 557, 443 (2001).

E16230