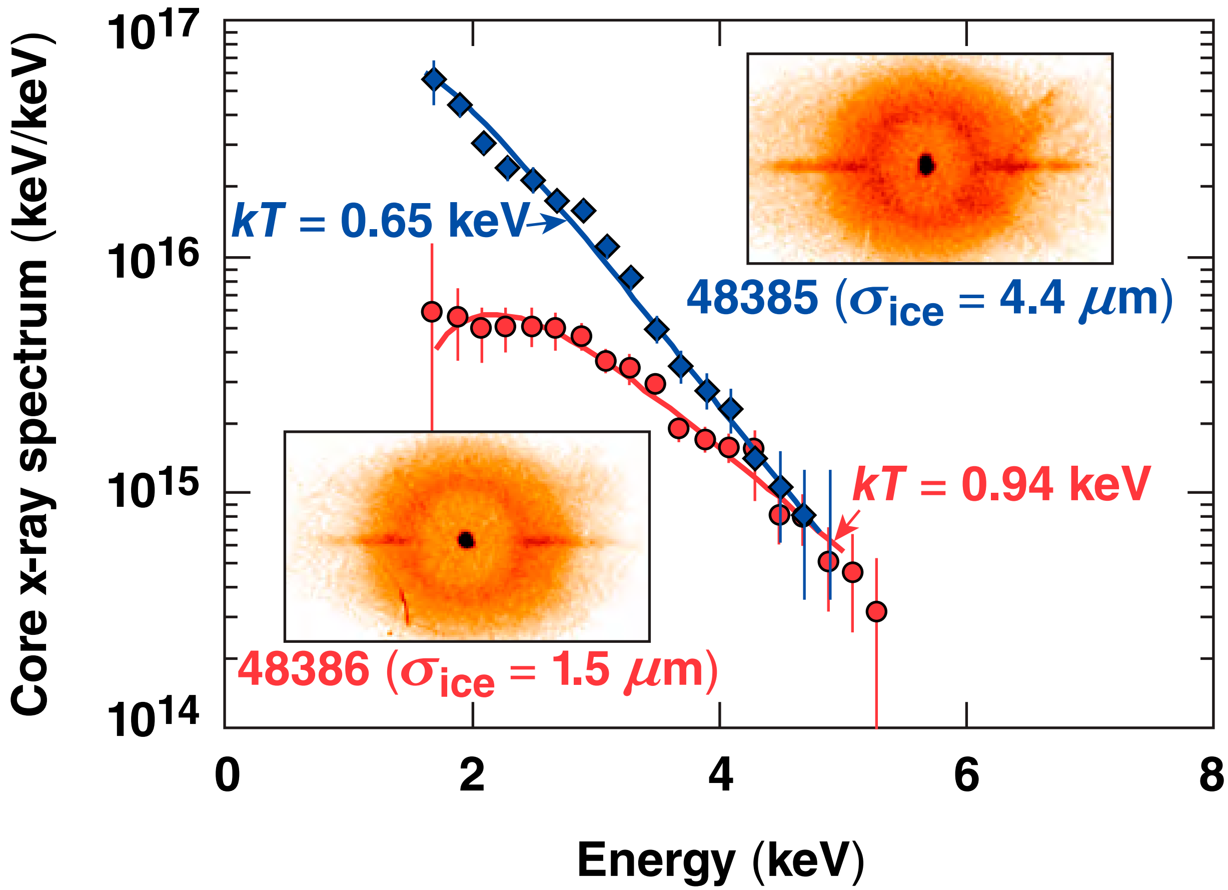
X-Ray Spectral Measurements of Cryogenic Capsules Imploded by OMEGA



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Division of Plasma Physics
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Summary

X-ray spectral measurements diagnose conditions in the compressed plasma

- Time-integrated, space-resolved core x-ray spectra are obtained with both pinhole cameras and Kirkpatrick–Baez microscopes dispersed by transmission gratings.
- The shapes of the spectra allow inference of the core electron temperature (kT_e) from the slope of the spectrum at high energies.
- In selected cases, the surrounding main fuel layer areal density (ρR_{fuel}) is inferred from absorption at low energies.
- These results provide important benchmarks for the predictions of 1-D and 2-D hydrocode simulations.

Collaborators

J. P. Knauer, T. C. Sangster, J. A. Delettrez, P. W. McKenty,
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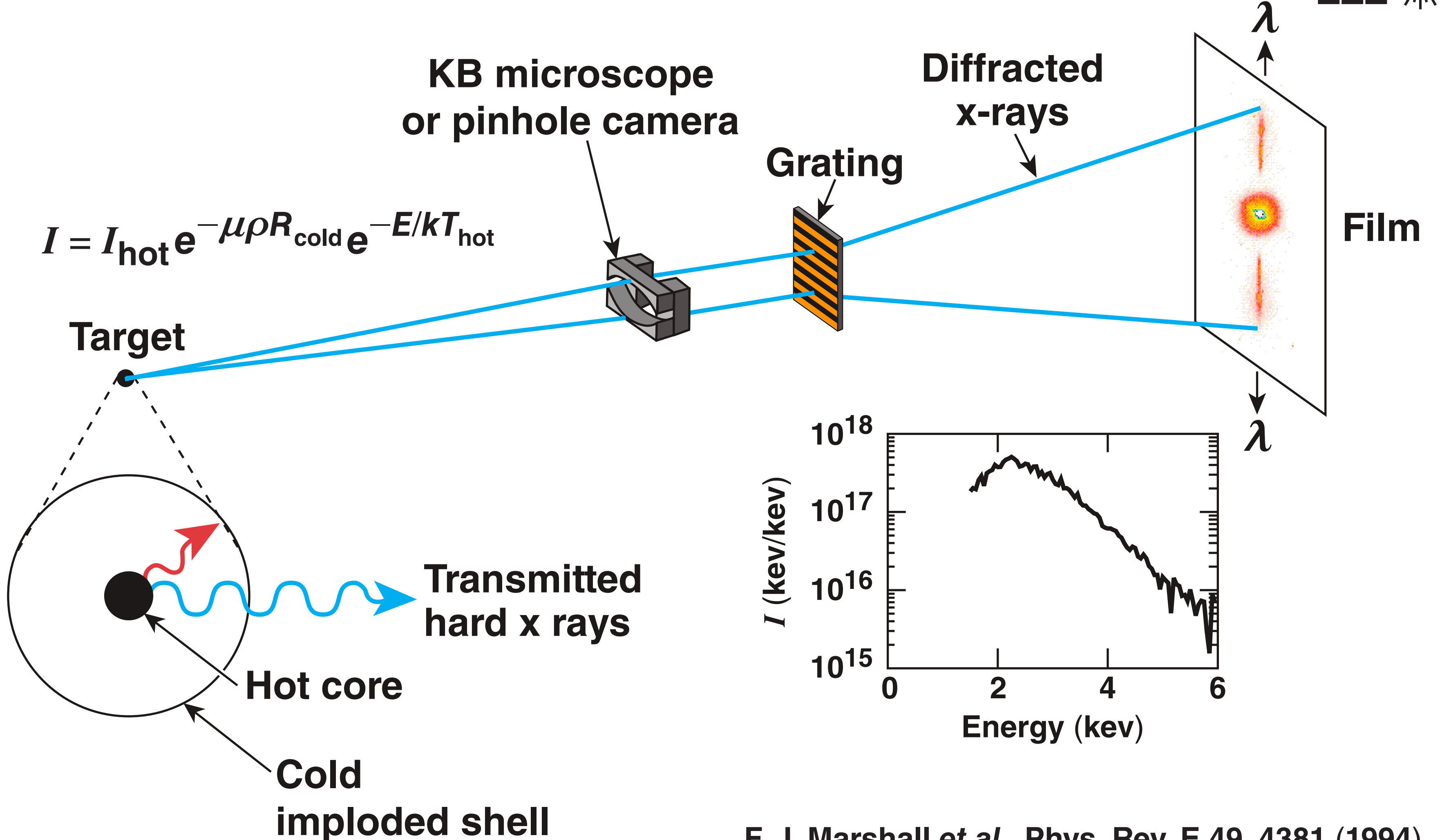
Related talk to follow by R. Epstein (JO3.00005)

Grating-Dispersed Imaging

X-ray emission from the core of an imploded OMEGA target is space and spectrally resolved, enabling the estimation of kT_{hot} and ρR_{cold}



E16280

F. J. Marshall *et al.*, Phys. Rev. E 49, 4381 (1994).
F. J. Marshall *et al.*, Phys. Plasmas 7, 1006 (2000).

Cryogenic targets should exhibit an exponential tail with low energy absorption by the cold fuel

UR LLE

- Thermal bremsstrahlung from the hot core*

$$\varepsilon_{ff}(\nu) = 6.8 \times 10^{-38} Z^2 N_e N_i T^{-1/2} e^{-h\nu/kT} g_{ff}(\nu, T) \text{ erg s}^{-1} \text{ cm}^{-3}$$

$$\varepsilon_{ff}(\nu) \propto e^{-h\nu/kT_{hot}}$$

- Absorption by the main fuel layer (free-free absorption)*

$$I(\nu) = I_{hot}\, e^{-\mu\rho R_{fuel}}$$

$$\mu(\nu) = 3.7 \times 10^8\, \nu^{-3} Z^2 N_e N_i T^{-1/2} \rho^{-1} (1 - e^{-h\nu/kT})\, g_{ff}(\nu, T) \text{ cm}^{-2} \text{ g}^{-1}$$

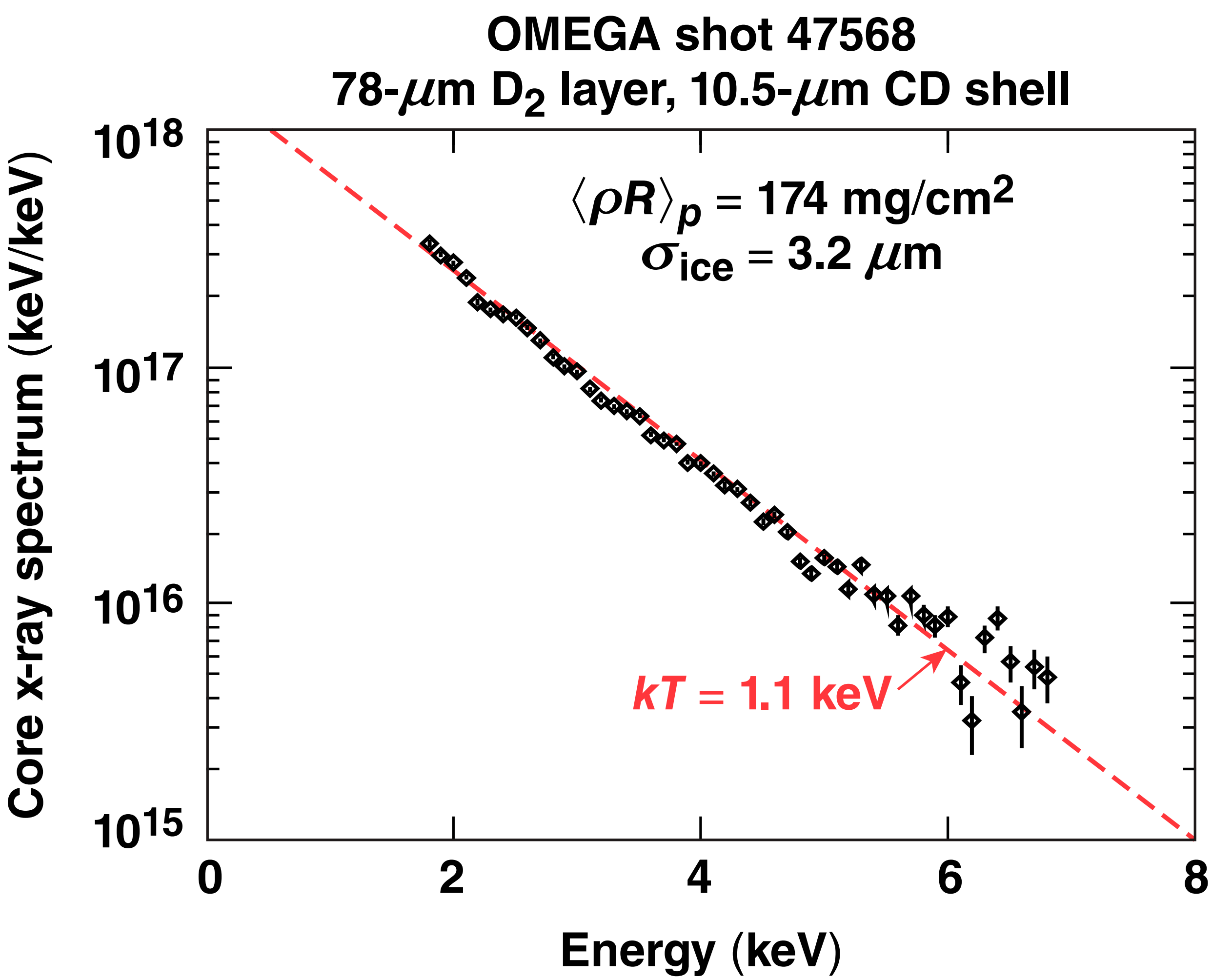
$$\mu(\nu) \propto \rho\ E^{-3}\, T^{-1/2} \quad \text{(optical depth} \propto \rho^2 R\text{)}$$

where $g_{ff}(\nu,T)$ is the velocity-averaged Gaunt factor.

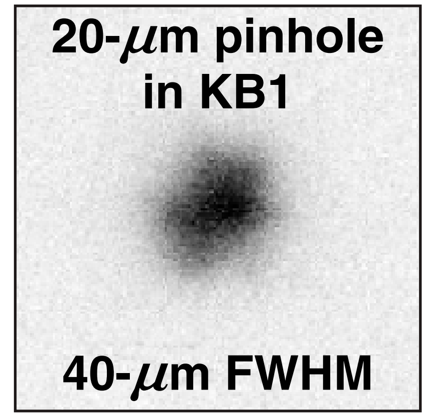
*G. B. Rybicki and A. P. Lightman, *Radiative Processes in Astrophysics* (Wiley and Sons, New York, 1979).

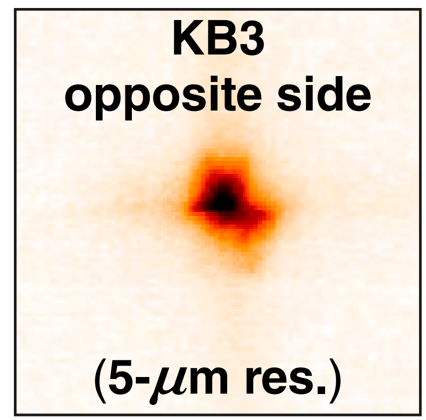
See also R. Epstein (JO3.00005) talk to follow

Typical x-ray spectra of OMEGA cryogenic targets are exponential with little sign of absorption



Core images
(2 to 7 keV)





200-μm regions

E16282

The low-energy portion of the spectrum has been measured with multiple methods to verify the shape

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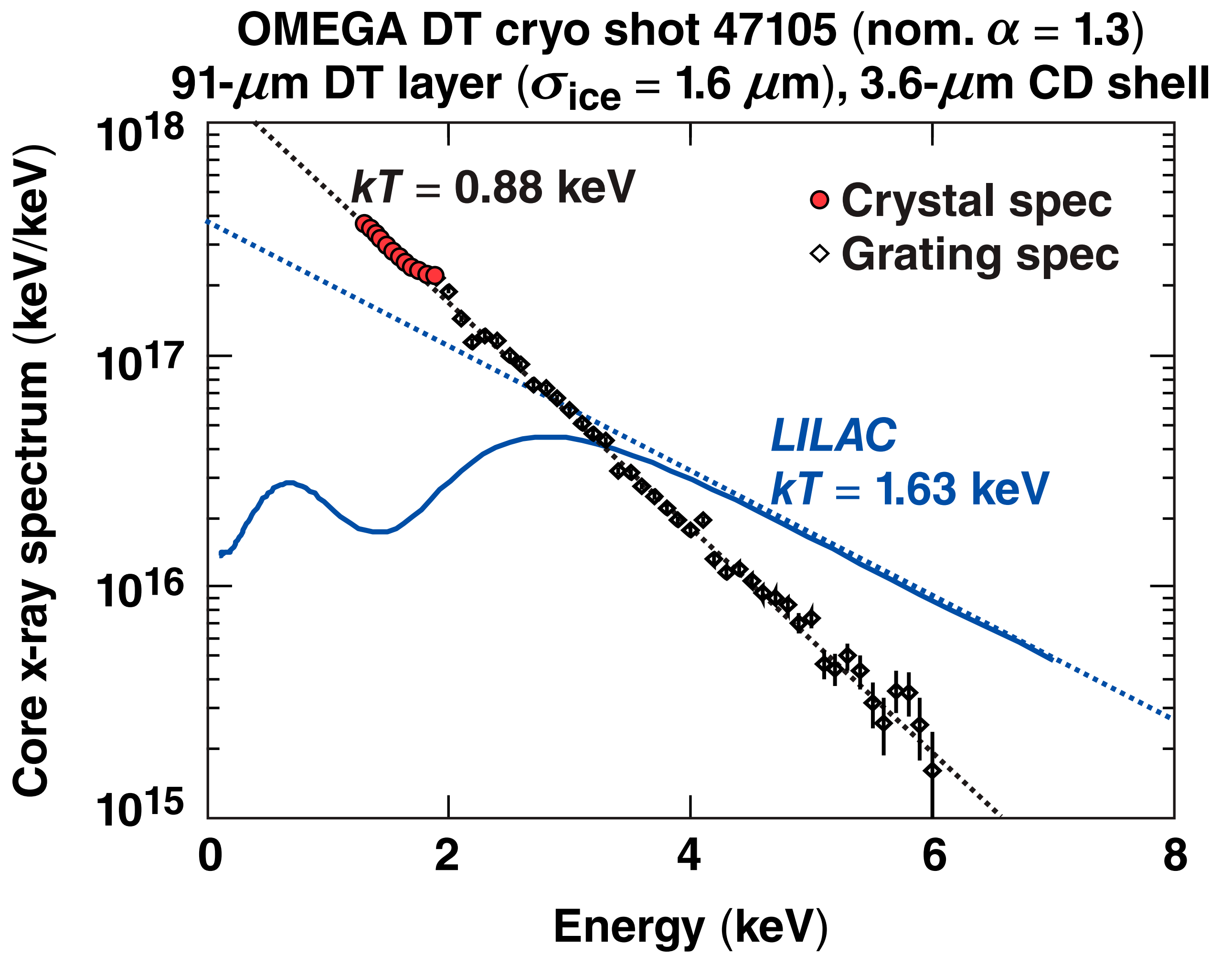
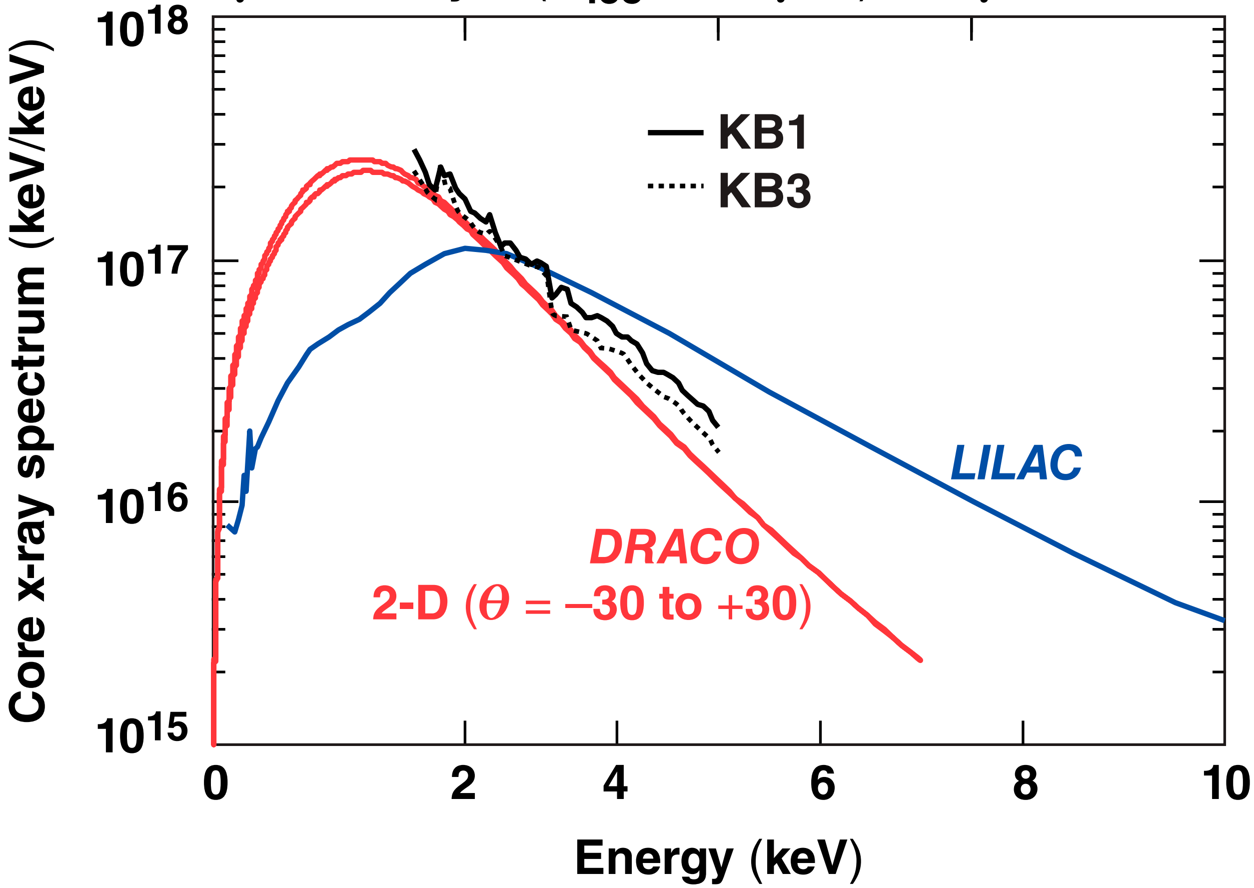


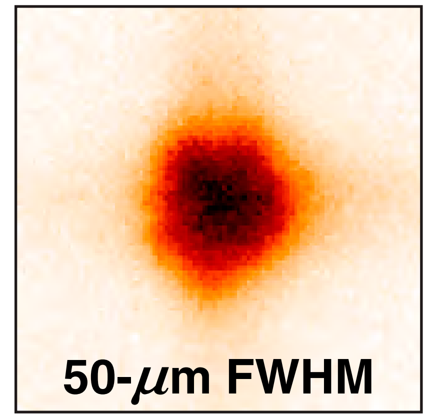
E16284

DRACO simulations explain the lack of absorption at low x-ray energies as being due to evolved perturbations

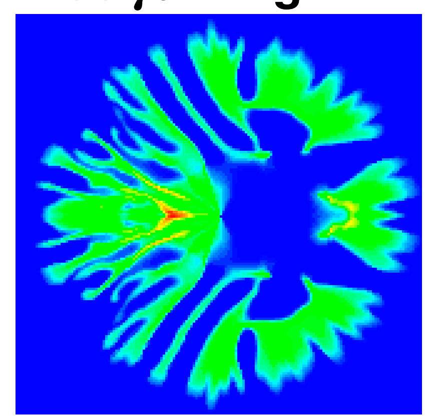
OMEGA shot 44240 (nom. α = 2)
91-μm DT layer (σ_{ice} = 0.8 μm), 3.6-μm CD shell



Core image
(2 to 7 keV)



200-μm regions



DRACO density contours at stagnation*

*Unstable implosion due to a high in-flight-aspect-ratio

E16283

A significantly different core size and x-ray spectra are seen when higher ρR is achieved

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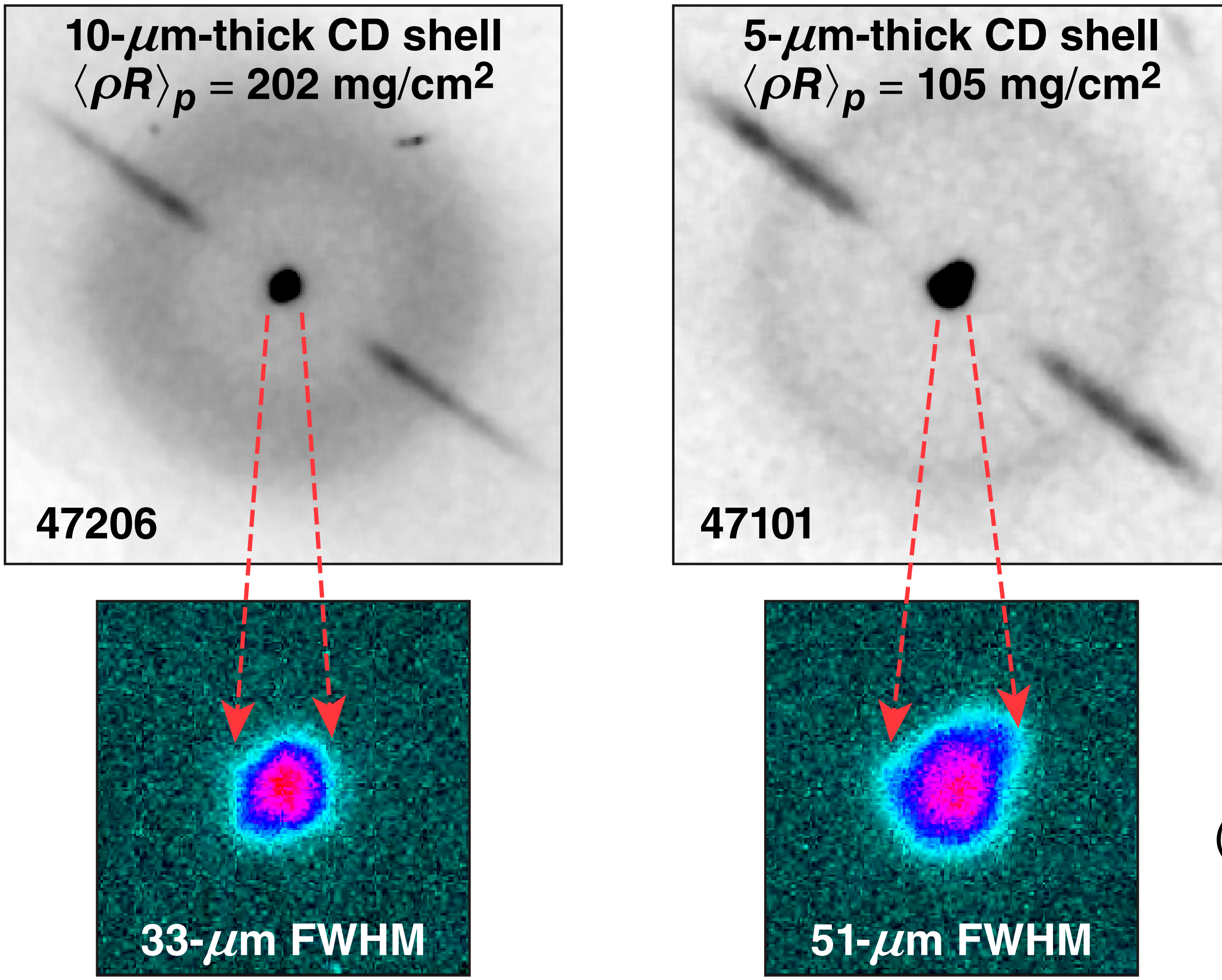
OMEGA cryogenic-D_2 target, grating-dispersed x-ray images



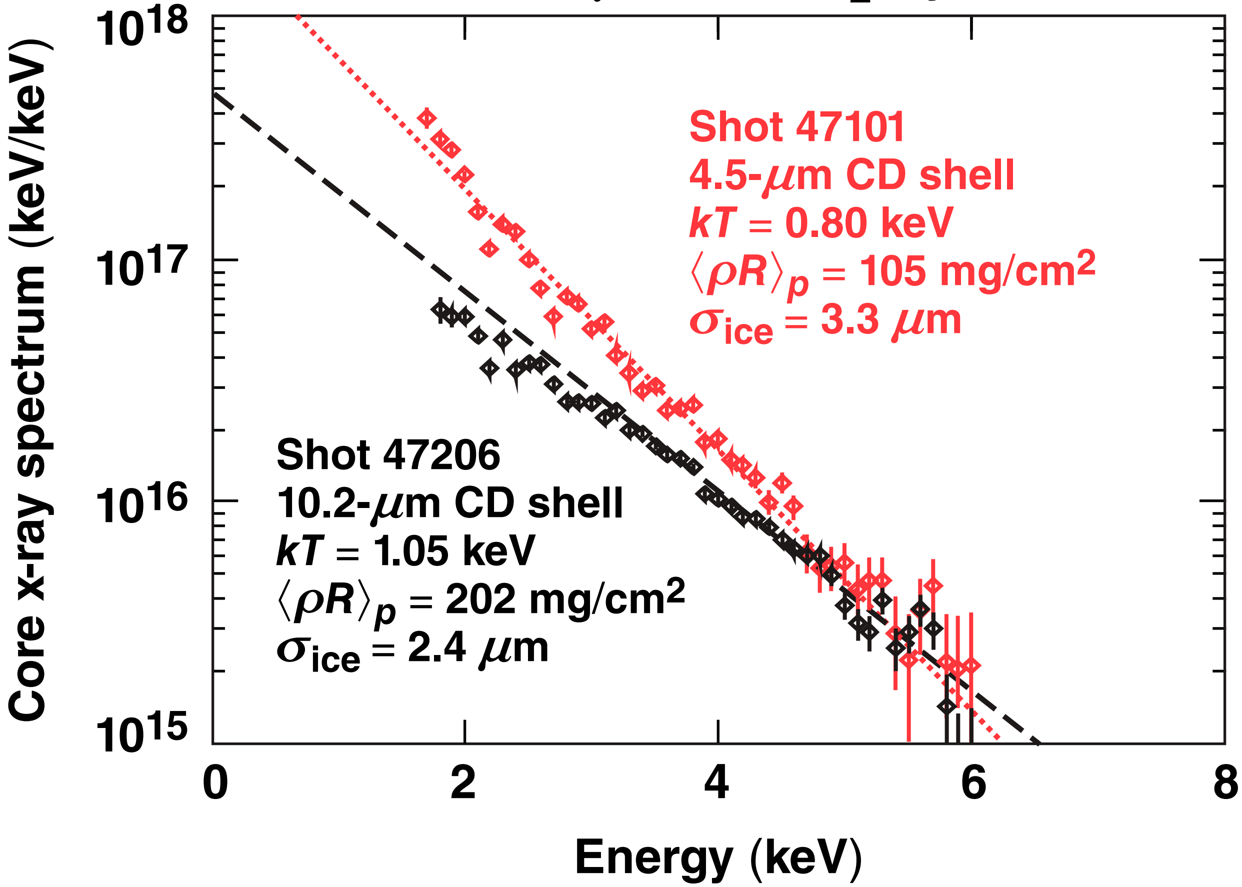
1-mm regions

200-µm regions (2 to 7 keV)

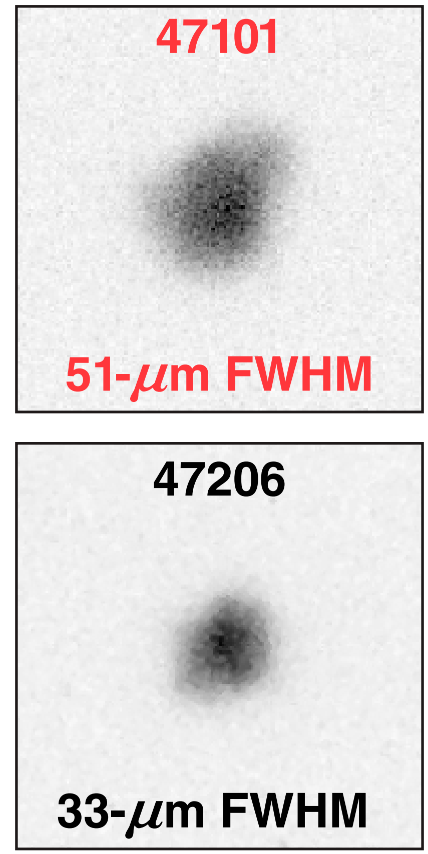
E16285

A significant difference is seen in both measured ρR and x-ray spectrum when thicker CD shells are used

OMEGA cryo shots with 95-μm-thick D_2 layers



20-μm resolution



200-μm regions (2 to 7 keV)

E16286

DRACO simulations are in excellent agreement* with the observed x-ray spectrum for high ρR and moderate ice roughness

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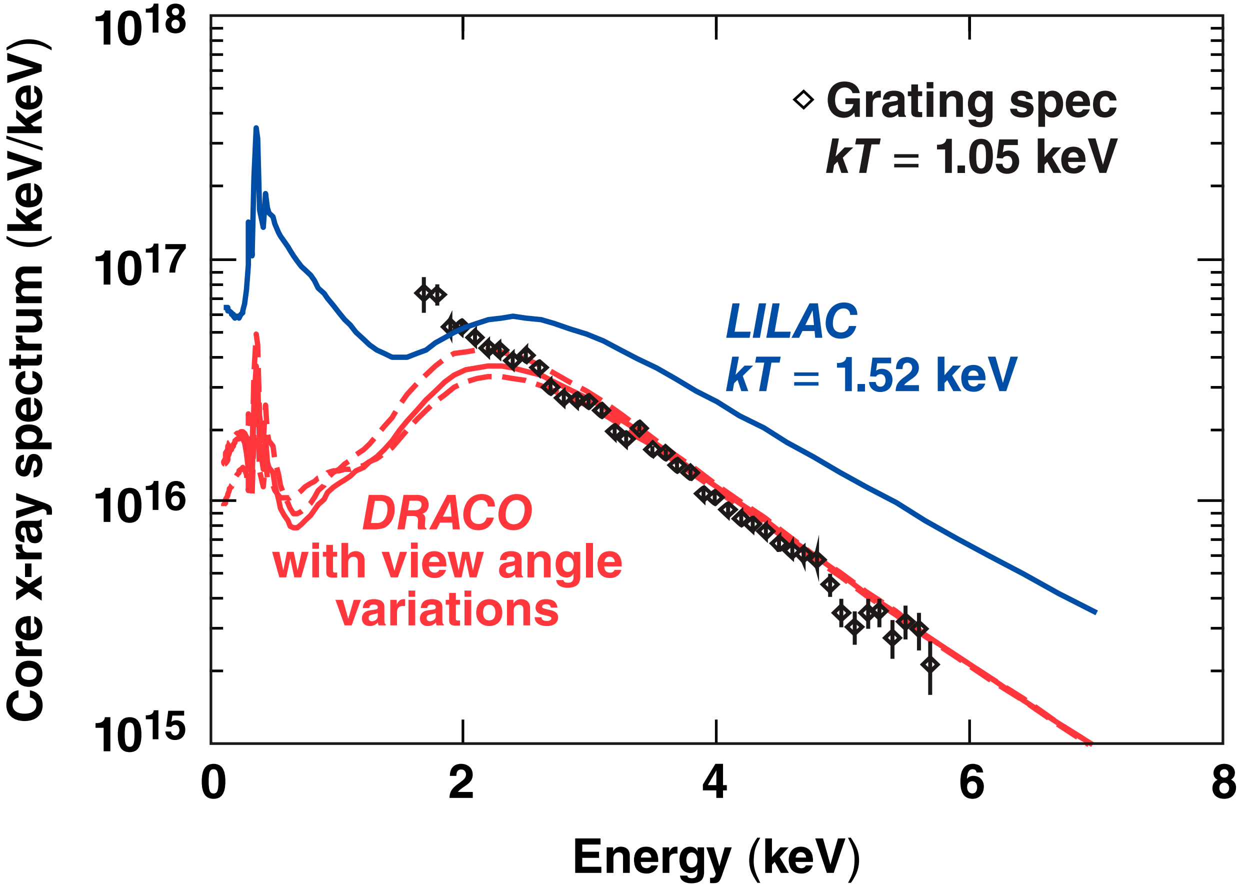
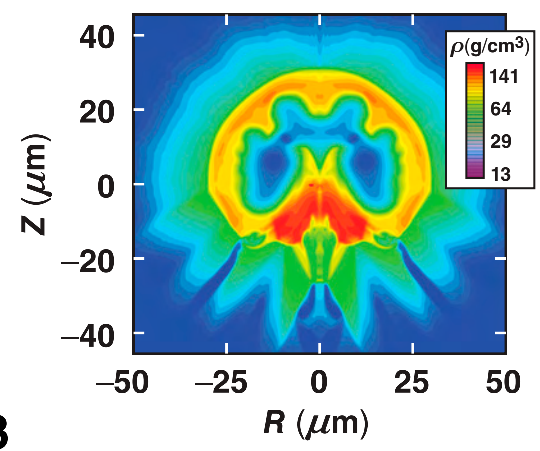


*with the exception of the very lowest energies where absorption by the cold fuel should occur

95-μm D_2 layer
10.2-μm CD shell
$\langle \rho R \rangle_p$ = 202 mg/cm^2
σ_{ice} = 2.4 μm

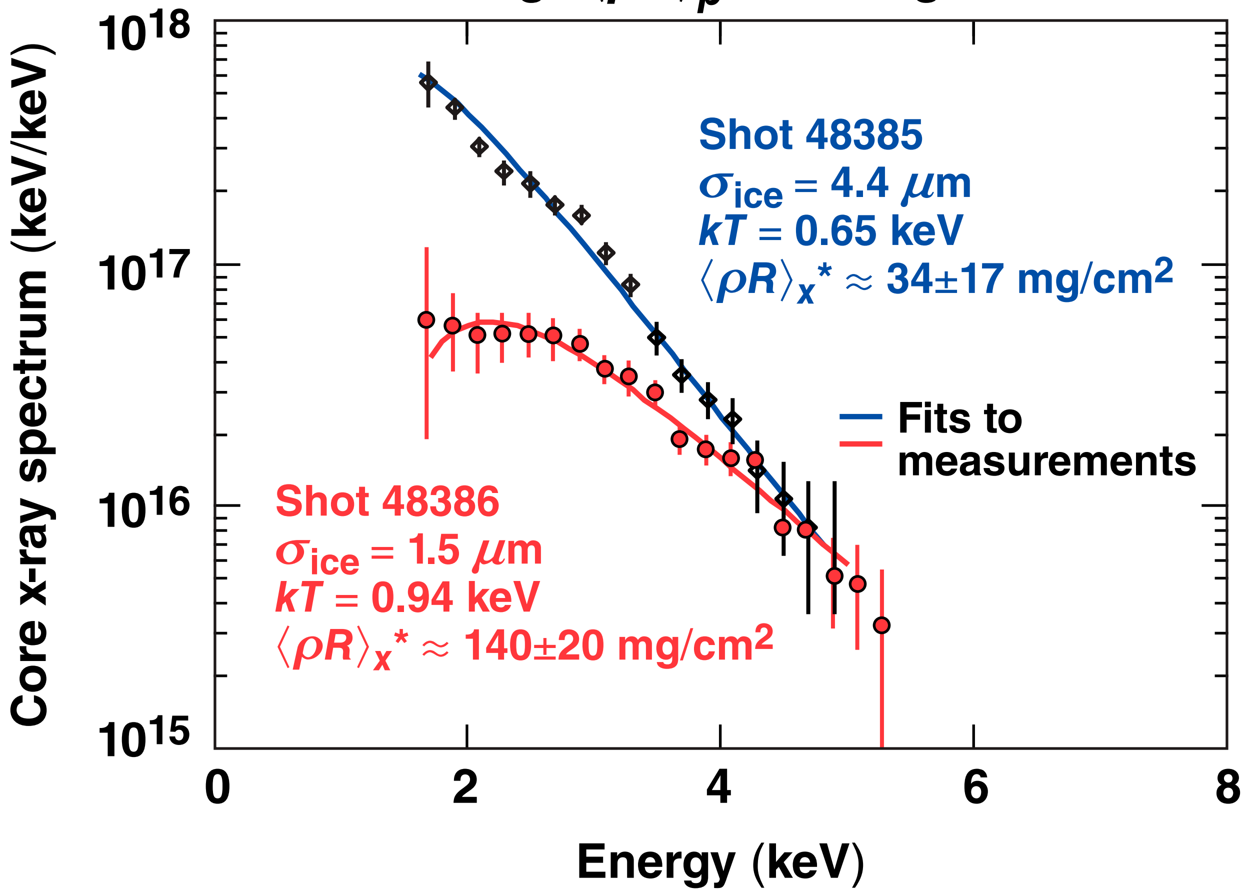


DRACO density contours at stagnation

E16287

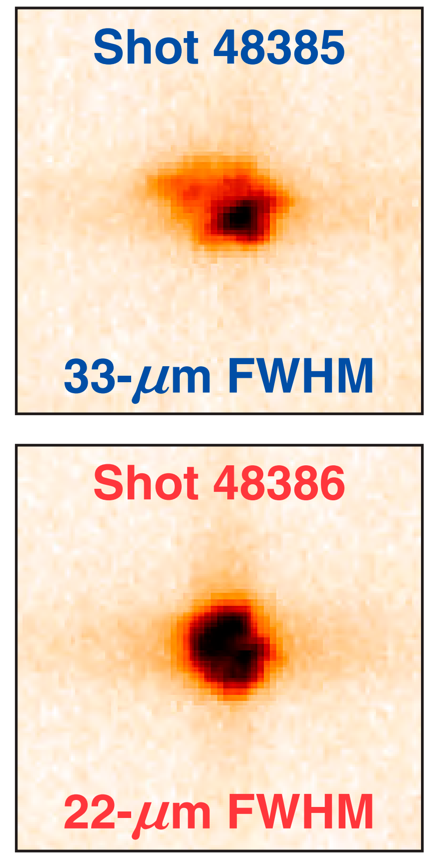
A large increase in observed absorption may be correlated with improved ice-layer uniformity

OMEGA cryo shots (nom. α = 2.5)
95-μm D_2 layers, 10-μm CD shells
average $\langle \rho R \rangle_p$ = 183 mg/cm^2



*dependent on assumed ρ, T, and Gaunt factor see R. Epstein (J03.00005 to follow)

GMXI CID x-ray images



200-μm regions (2 to 7 keV)

E16288

Summary/Conclusions

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