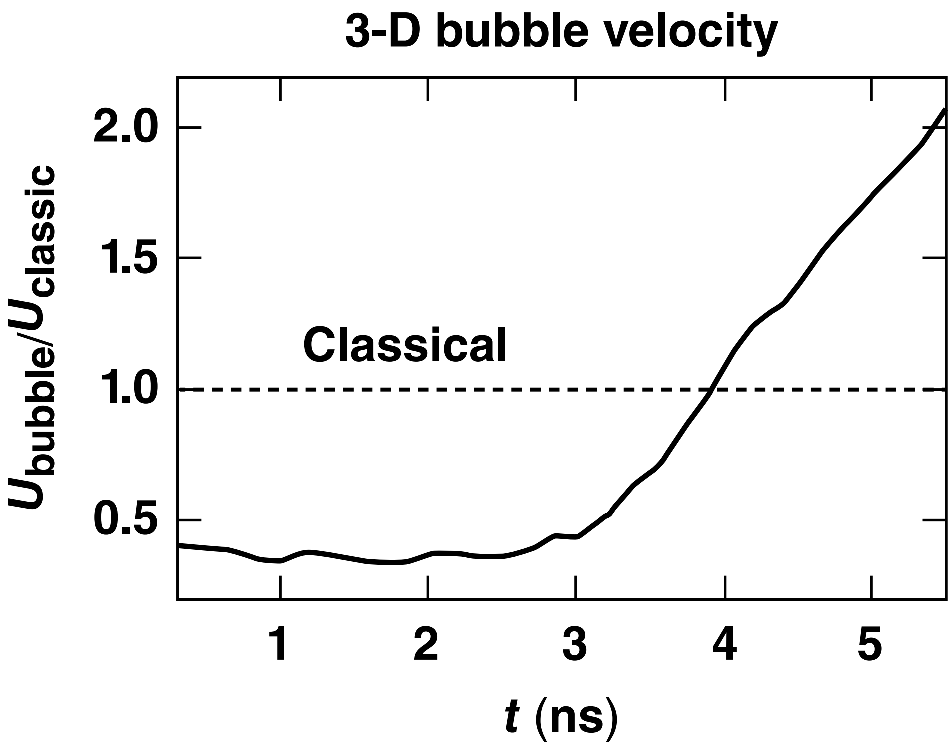
Bubble Acceleration in the Three-Dimensional Ablative Rayleigh–Taylor Instability



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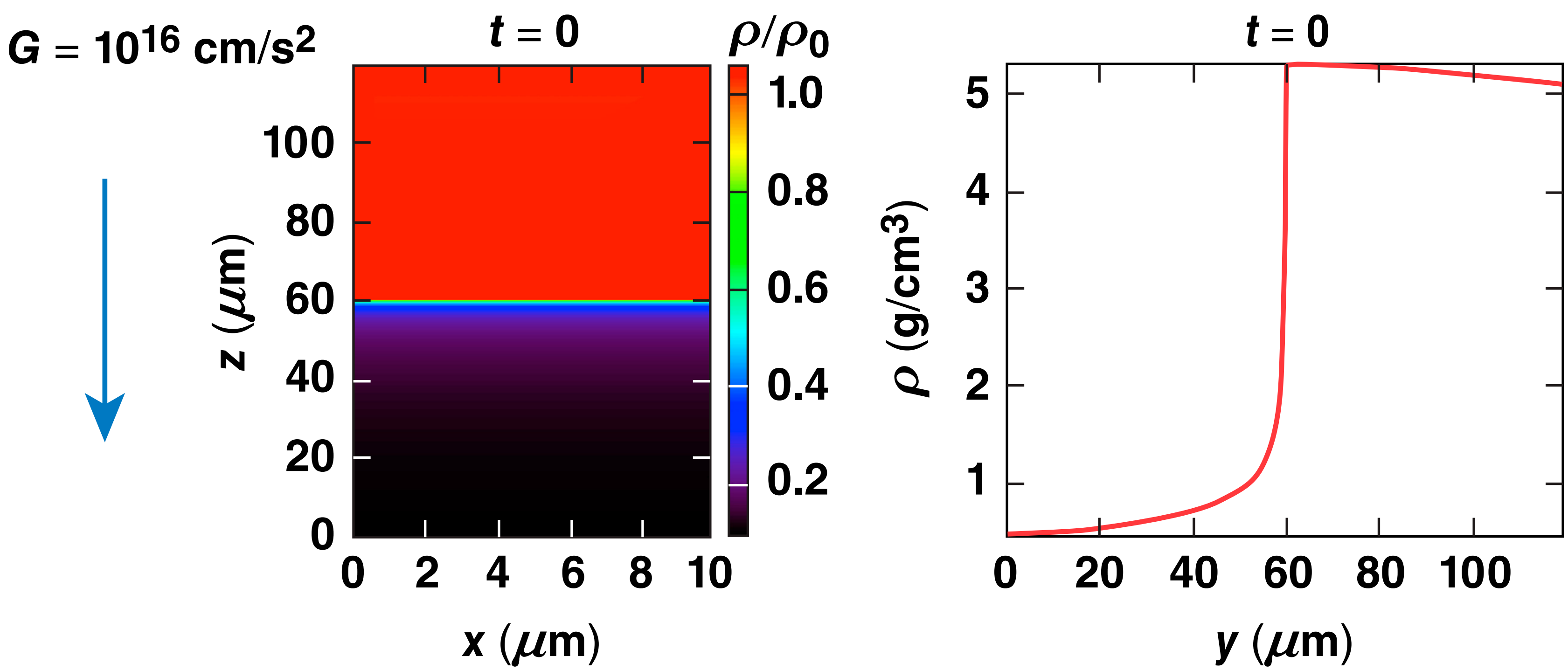
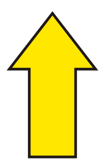
Summary

Three-dimensional simulations show that the bubble growth in the ablative Rayleigh–Taylor instablitiy (ARTI) is faster than classical RTI predictions

- The 3-D planar code *ART3D* is used to study the nonlinear evolution of the single-mode ablative RTI
- The bubble velocity in 3-D is faster than in 2-D
- No saturation is found for the 3-D ablative RTI bubble velocity, while the 2-D bubble velocity saturates above the classical value
- Vorticity accumulation inside the bubble caused by mass ablation accelerates the bubble to velocities well above the classical value

The ablative RTI simulations start from a quasi-equilibrium state





Heat flux

Perturbations

2-D: ~cos($k \times x$)

3-D: ~0.5 × [cos($k \times x$) + cos($k \times y$)]

Two-dimensional bubble velocity exceeds the classical value and saturates at about 2× the classical velocity

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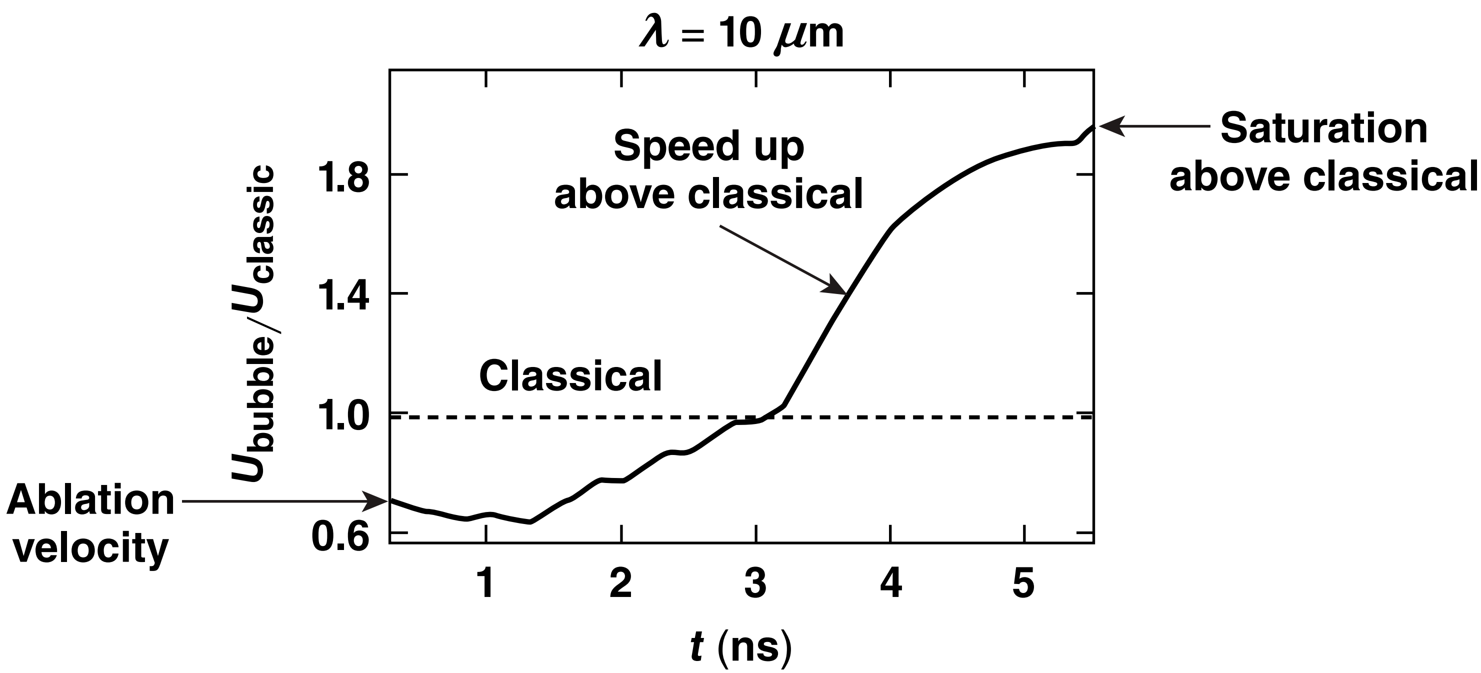
- The ablative RTI bubble saturates at about 2× the classic bubble velocity
- The second acceleration of the bubble is caused by mass ablation



$$U_{\text{classic–2-D}} = \sqrt{\frac{2A}{1+A}\frac{g}{3k}}$$

$$A = \frac{\rho_h - \rho_\ell}{\rho_h + \rho_\ell}$$

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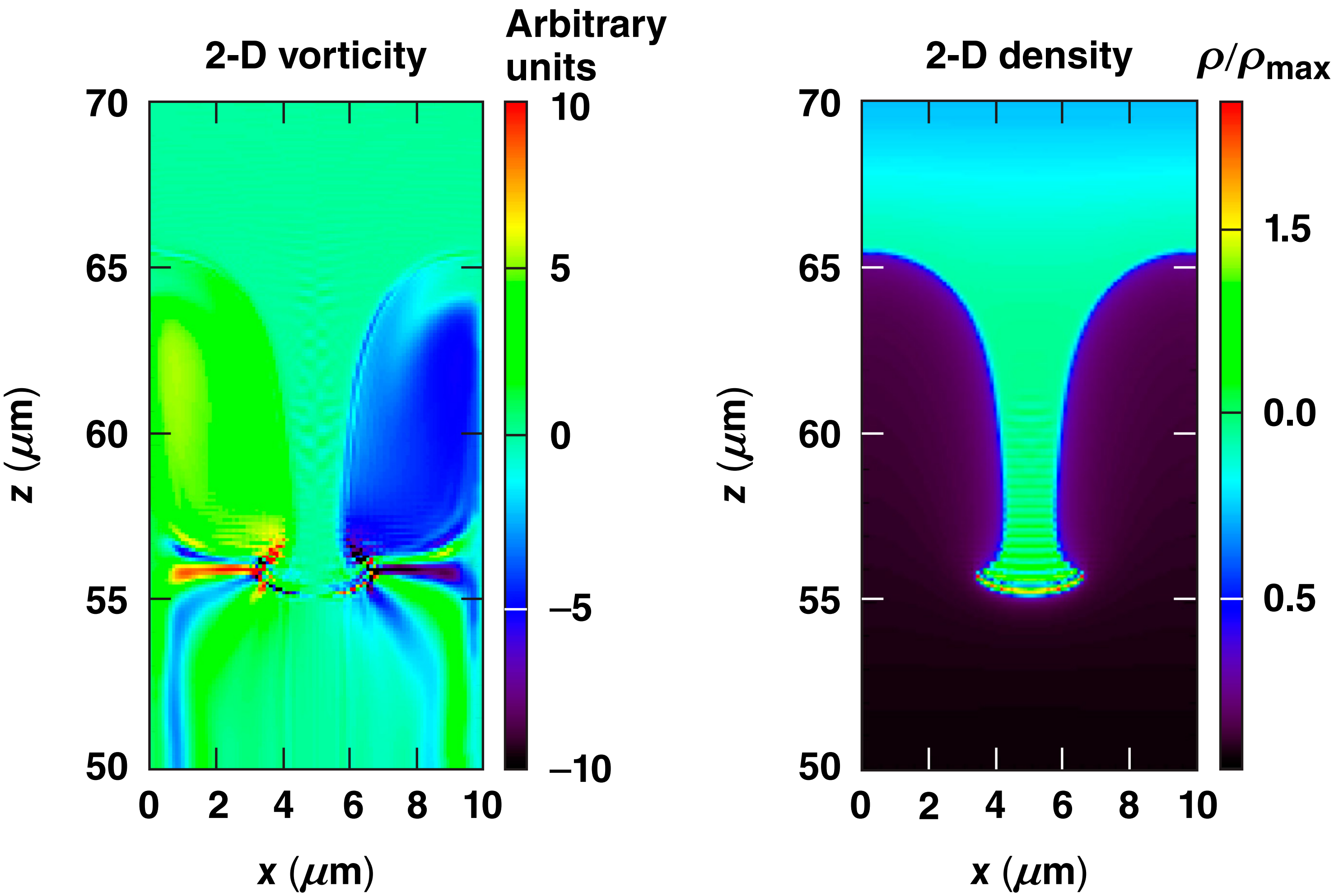
The acceleration above classical is caused by a vortex inside the bubble driven by mass ablation

2-D simulation



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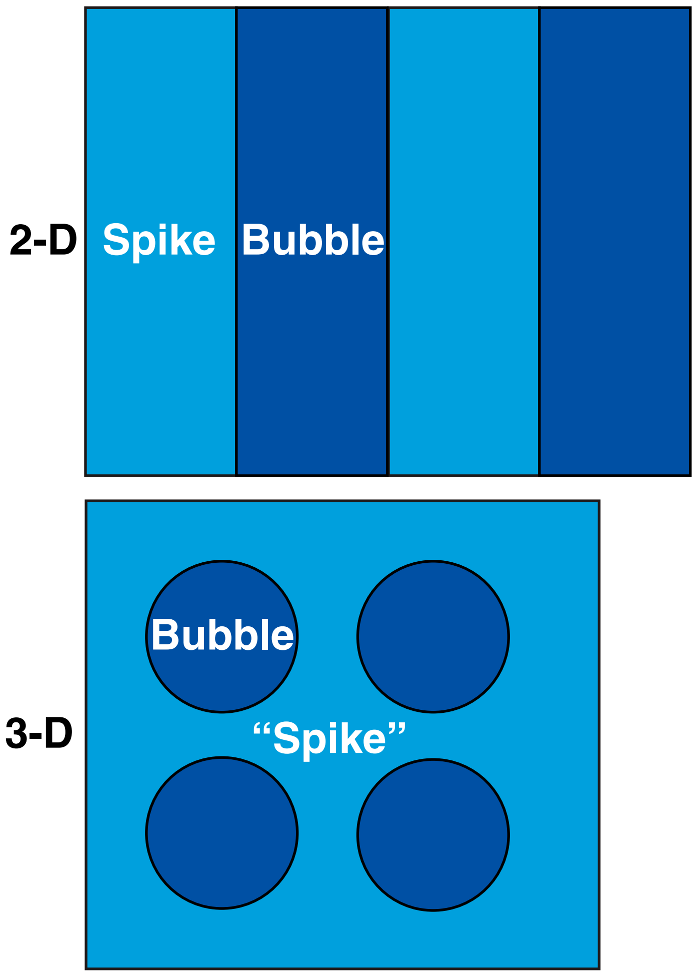
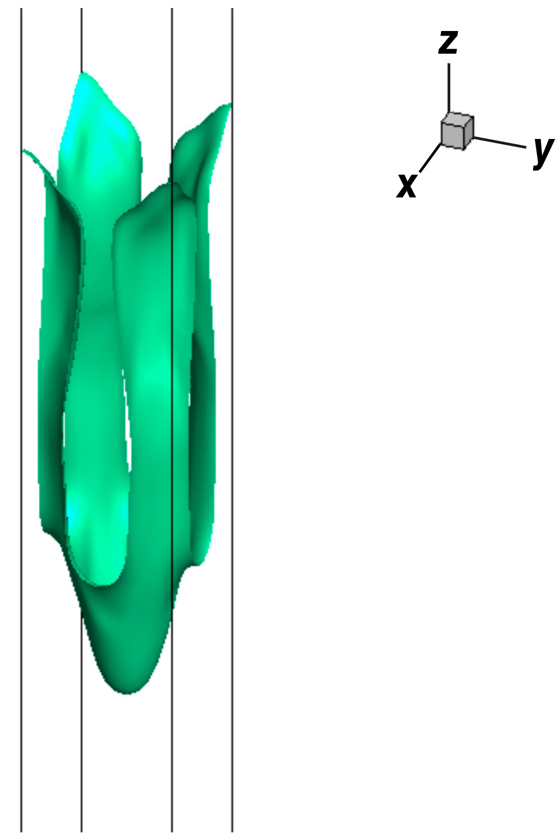
*R. Betti and J. Sanz, Phys. Rev. Lett. 97, 205002 (2006).

Three-dimensional topology is significantly different from 2-D

Top views



Isodensity surface of $\rho = 3$ g/cm^3 at $t = 5.4$ ns in the 3-D simulation



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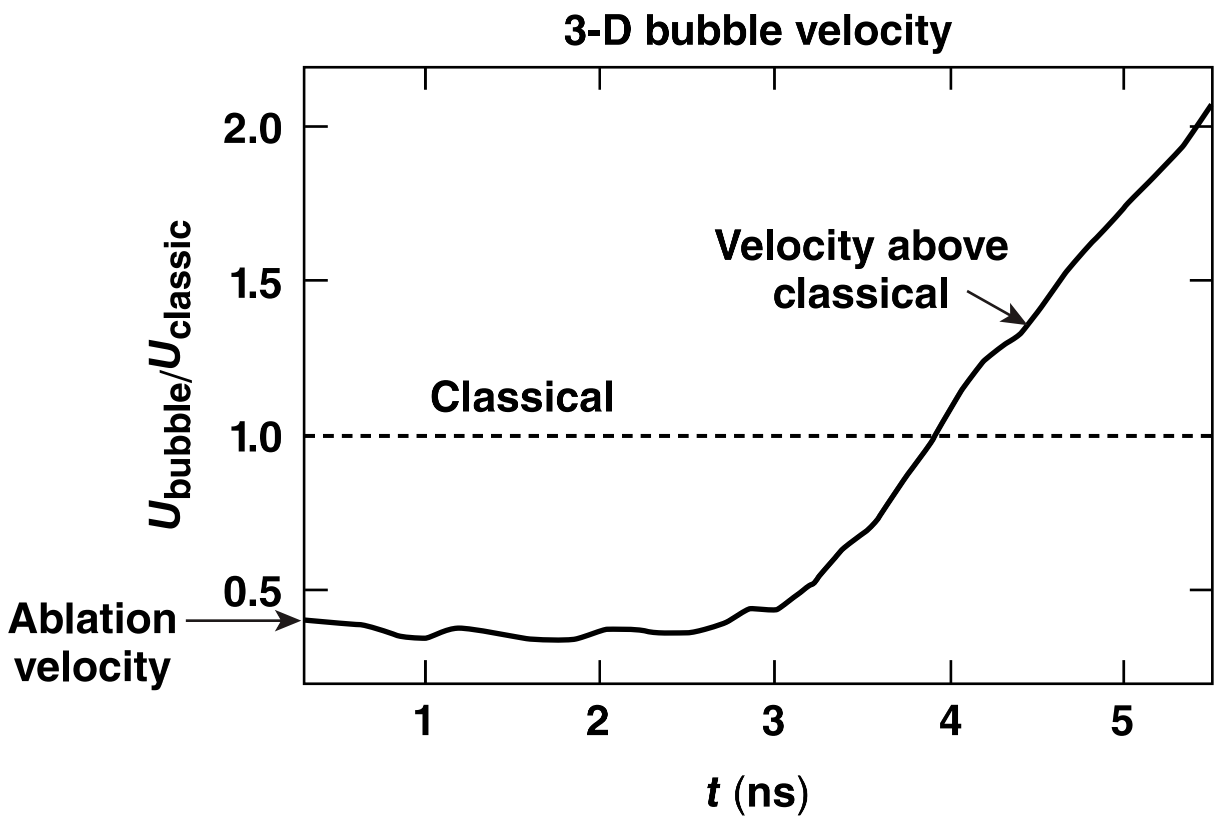
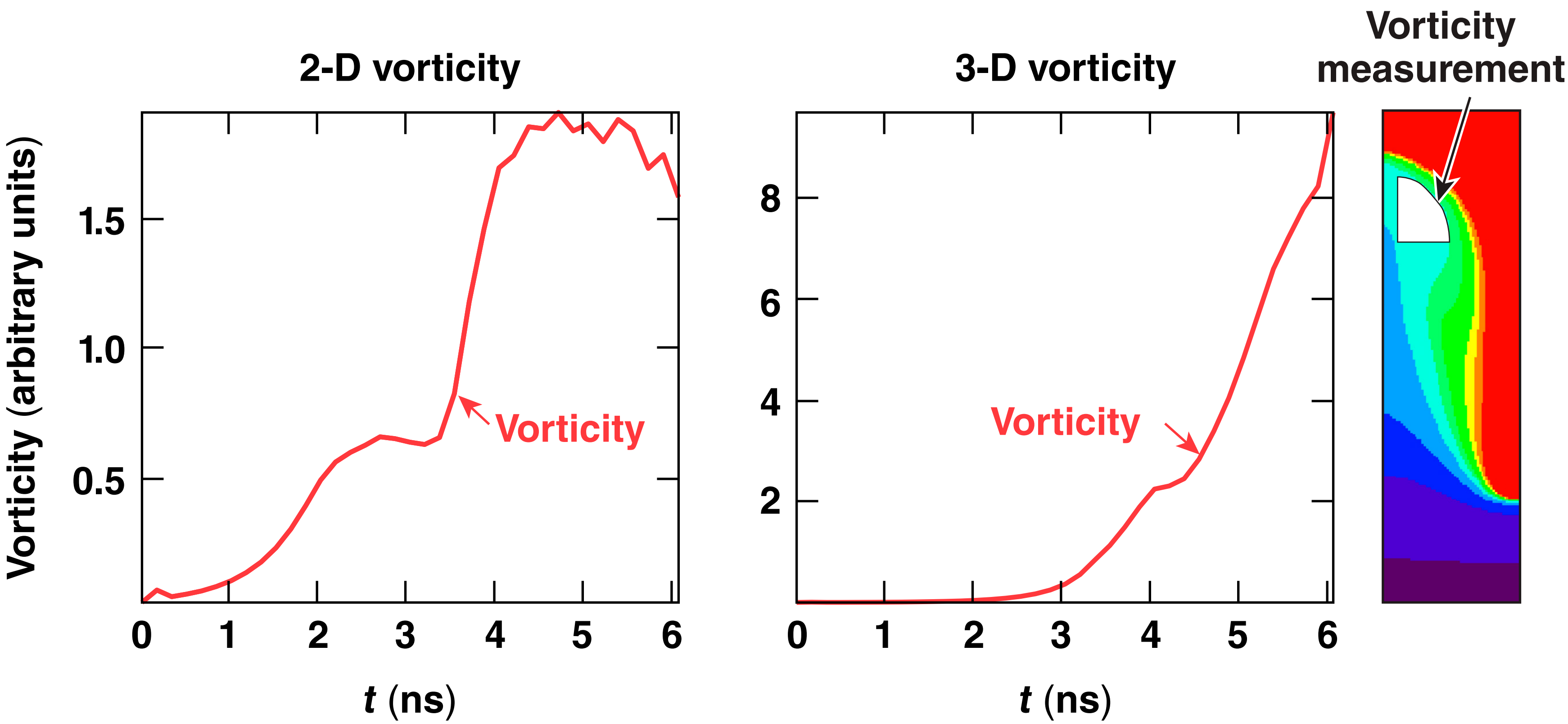
Unlike in 2-D, the 3-D bubble velocity does not show saturation in the ablative RTI



The vorticity near the bubble tip saturates in 2-D but keeps increasing in 3-D



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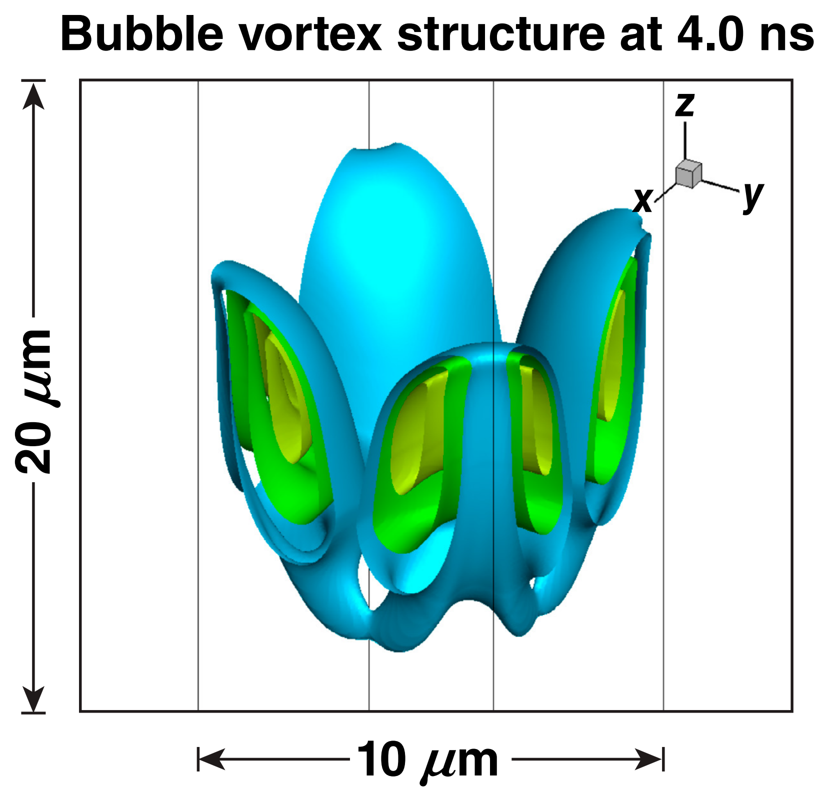
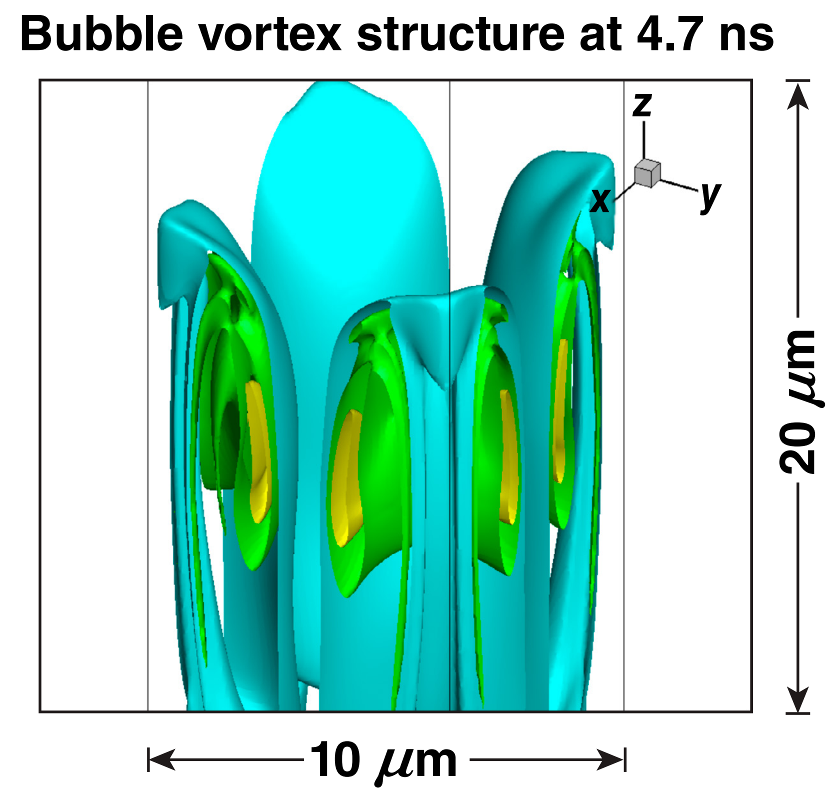
The bubble and the vortex inside the bubble become distorted in the highly nonlinear phase





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Summary/Conclusions

Three-dimensional simulations show that the bubble growth in the ablative Rayleigh–Taylor instablitiy (ARTI) is faster than classical RTI predictions

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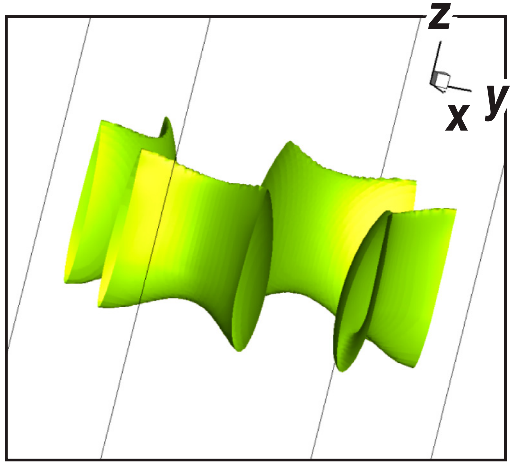
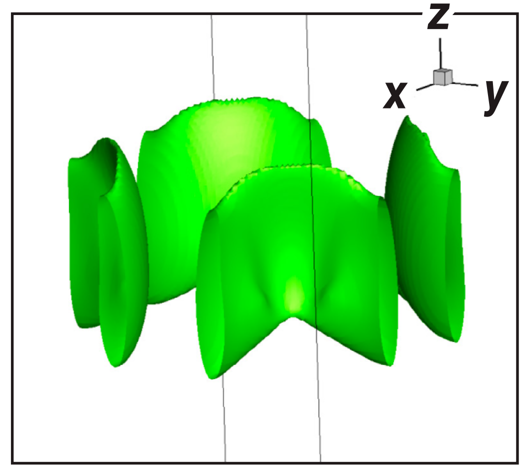
- **The 3-D planar code *ART3D* is used to study the nonlinear evolution of the single-mode ablative RTI**
- **The bubble velocity in 3-D is faster than in 2-D**
- **No saturation is found for the 3-D ablative RTI bubble velocity, while the 2-D bubble velocity saturates above the classical value**
- **Vorticity accumulation inside the bubble caused by mass ablation accelerates the bubble to velocities well above the classical value**

The vortex tubes' distortion can cause the vorticity growing at the bubble tip

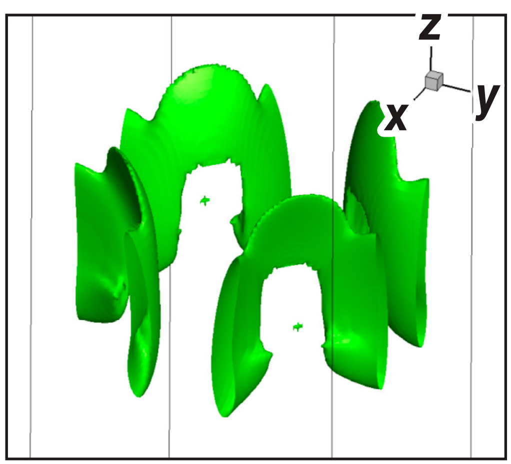
I_{step} = 52,000; t = 4.36 ns

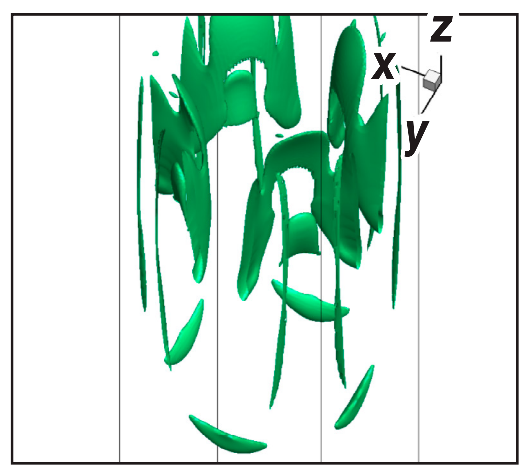


I_{step} = 54,000



I_{step} = 56,000





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The 3-D vortex structure is more complicated than 2-D