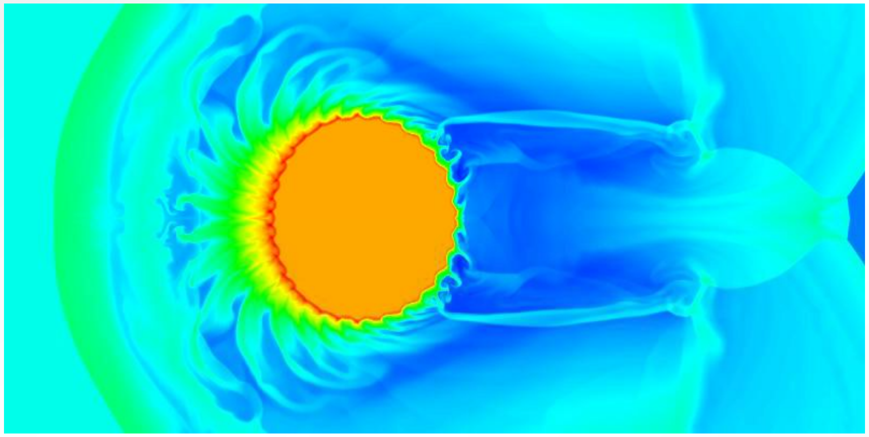
Rapid Turbulization Arising from Vortex Double Layers in Interactions of "Complex" Blast Waves and Cylindrical/Spherical Bubbles



S. Zhang[1], N. J. Zabusky[1], K. Nishihara[2], and Y-G. Kang[2]

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[1] *Lab of Visiometrics and Modeling, Dept. of Mechanical & Aerospace Engineering, Rutgers University, USA*

[2]*Institute of Laser Engineering, Osaka University, Japan*

Motivations

1. Supernova 1987A: Hydrodynamics of complex blast wave (*shock-contact-shock*) and ring interaction;
2. Upstream-ring erosion [Borkowski, Blondin & McCray, 1997];
3. Emergence and significance of vortex double layer, vortex projectiles due to the primary and secondary deposition of baroclinic vorticity;
4. Numerical simulations (PPM) at extremely high density ratio (up to 5500) and Mach numbers (up to 70);
5. Compare simulation with laser experiment[Kang et al, 2001];
6. Prediction of the late time behavior

Motivations Cont.

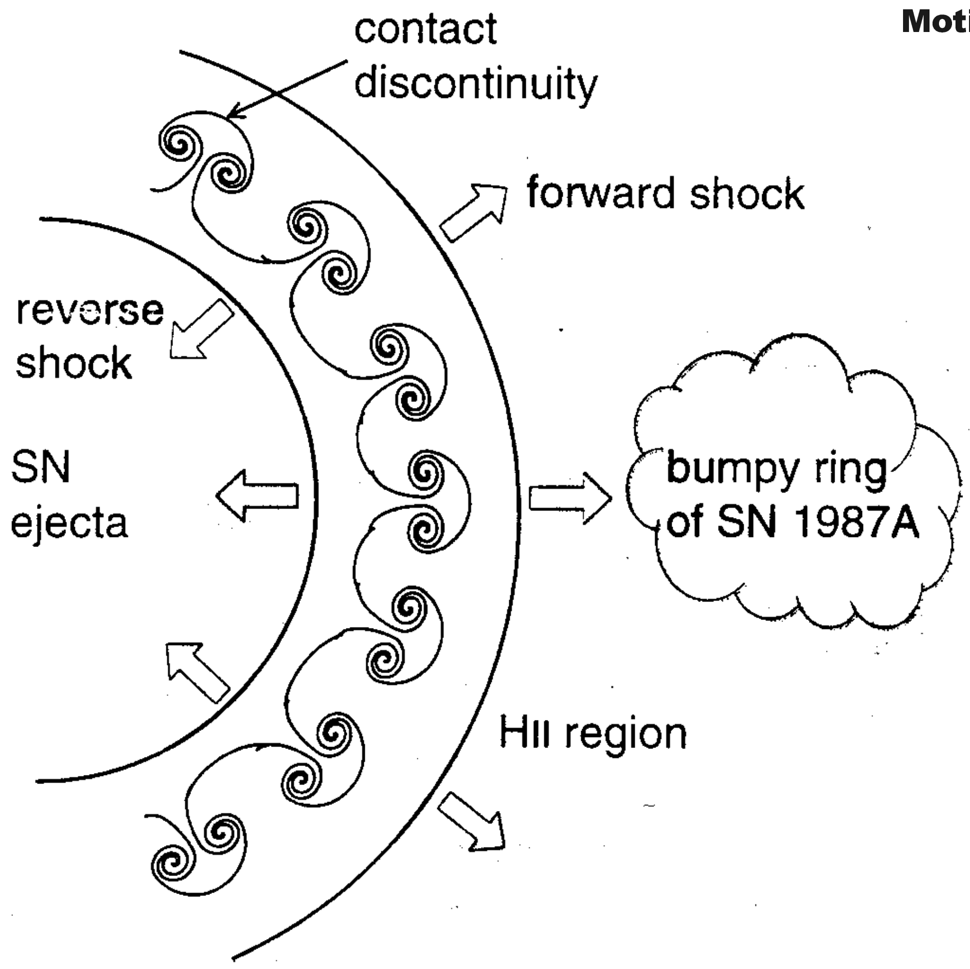


Fig.1. Turbulent contact discontinuity of the circumstellar region and the bumpy ring of SN 1987A: a more realistic situation

Motivations Cont.

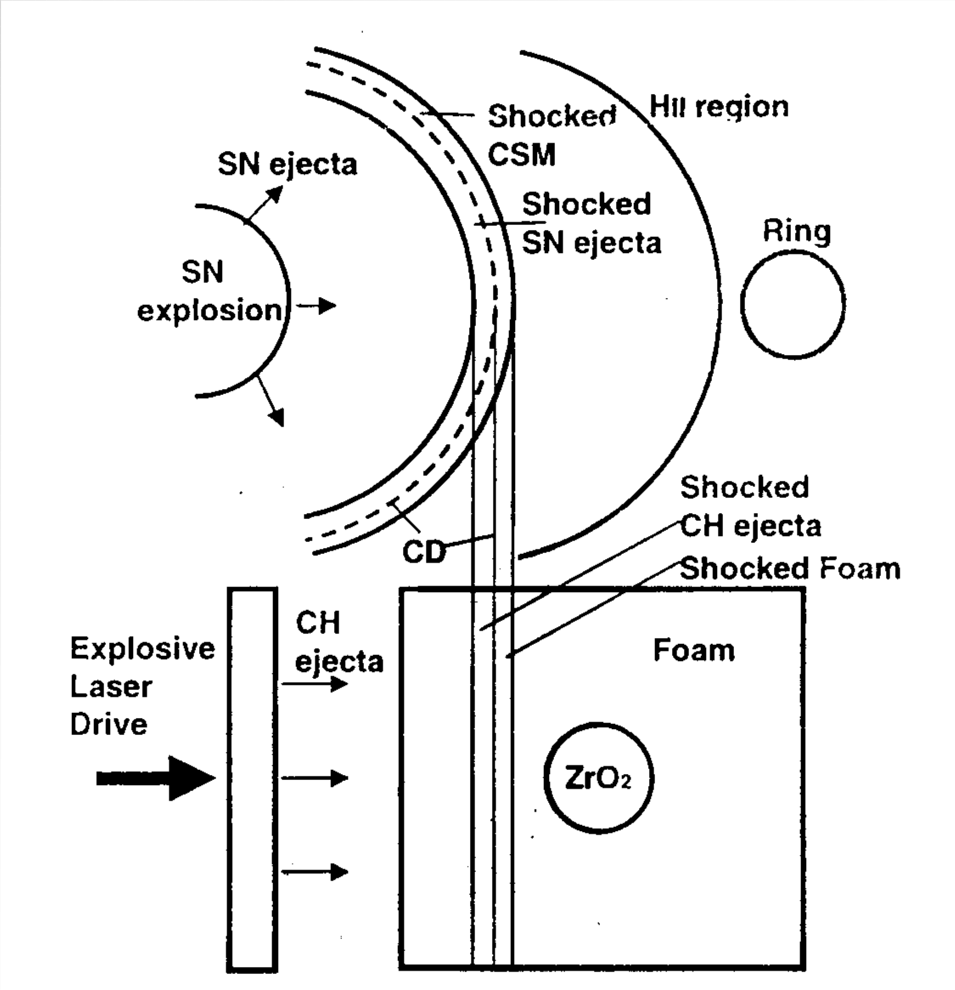


Fig. 2. Schematic structure of the shocked region, the circumstellar region and the ring of SN1987A with an laboratory experiment. The ejected material (SN ejecta and the CH ejecta) and the low density medium (CSM and the foam) are separated by a contact discontinuity (CD).

Part I: Simulations ---- Cylindrical bubble

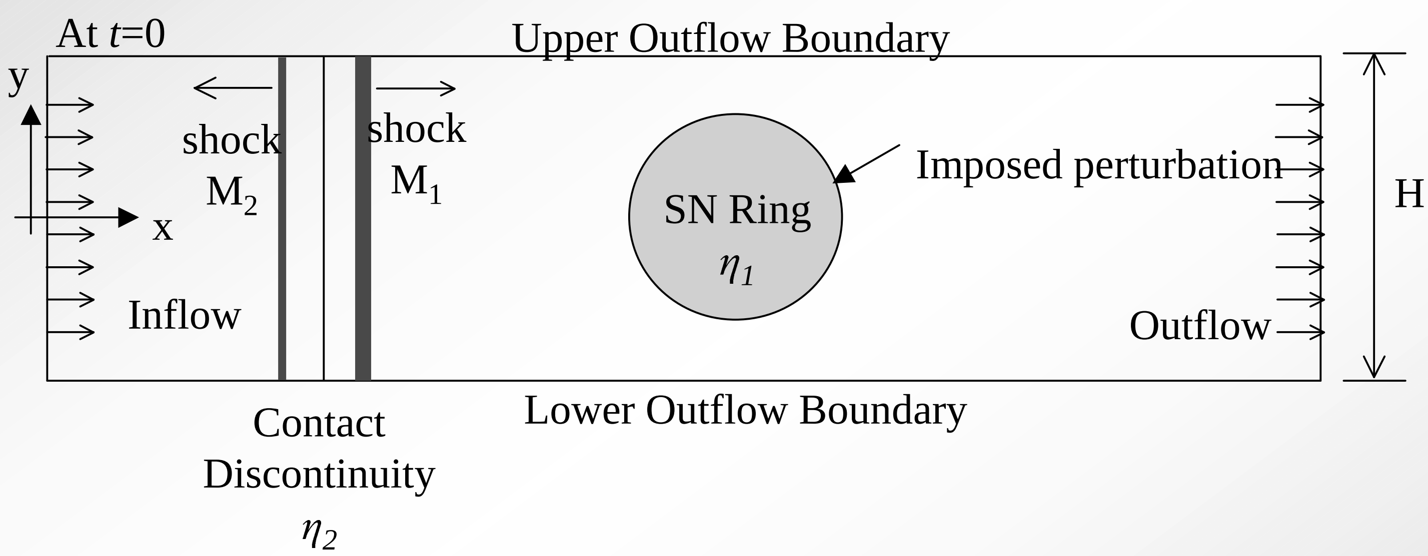


Fig. 3 Schematic of the computational domain and initial condition: Blast wave/SN Ring

Part I: Simulations Cont.

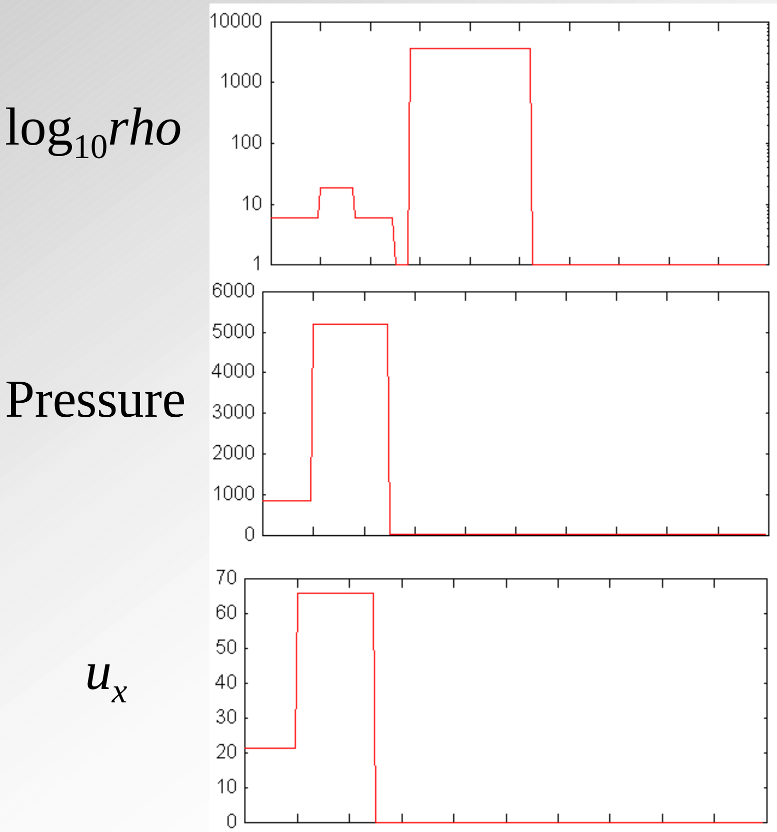


Fig. 4 Initial profiles of density (log scale), pressure, and x-velocity

Parameter Space:

- M_1 = 66.77
- η_1=5000
- η_2=4.0

Numerical Method:

- Compressible Euler Equation
- Piecewise Parabolic Method [Woodward & Colella, 1984]

Global quantification:

Part I: Simulations Cont.

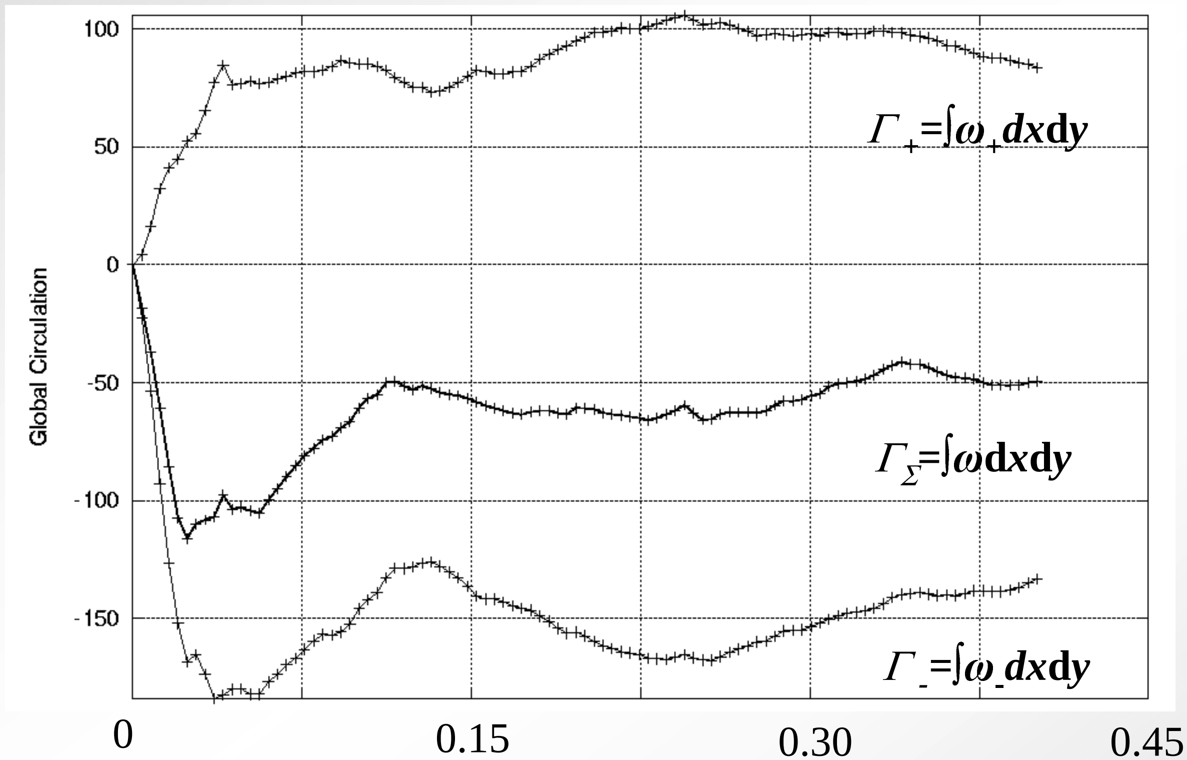
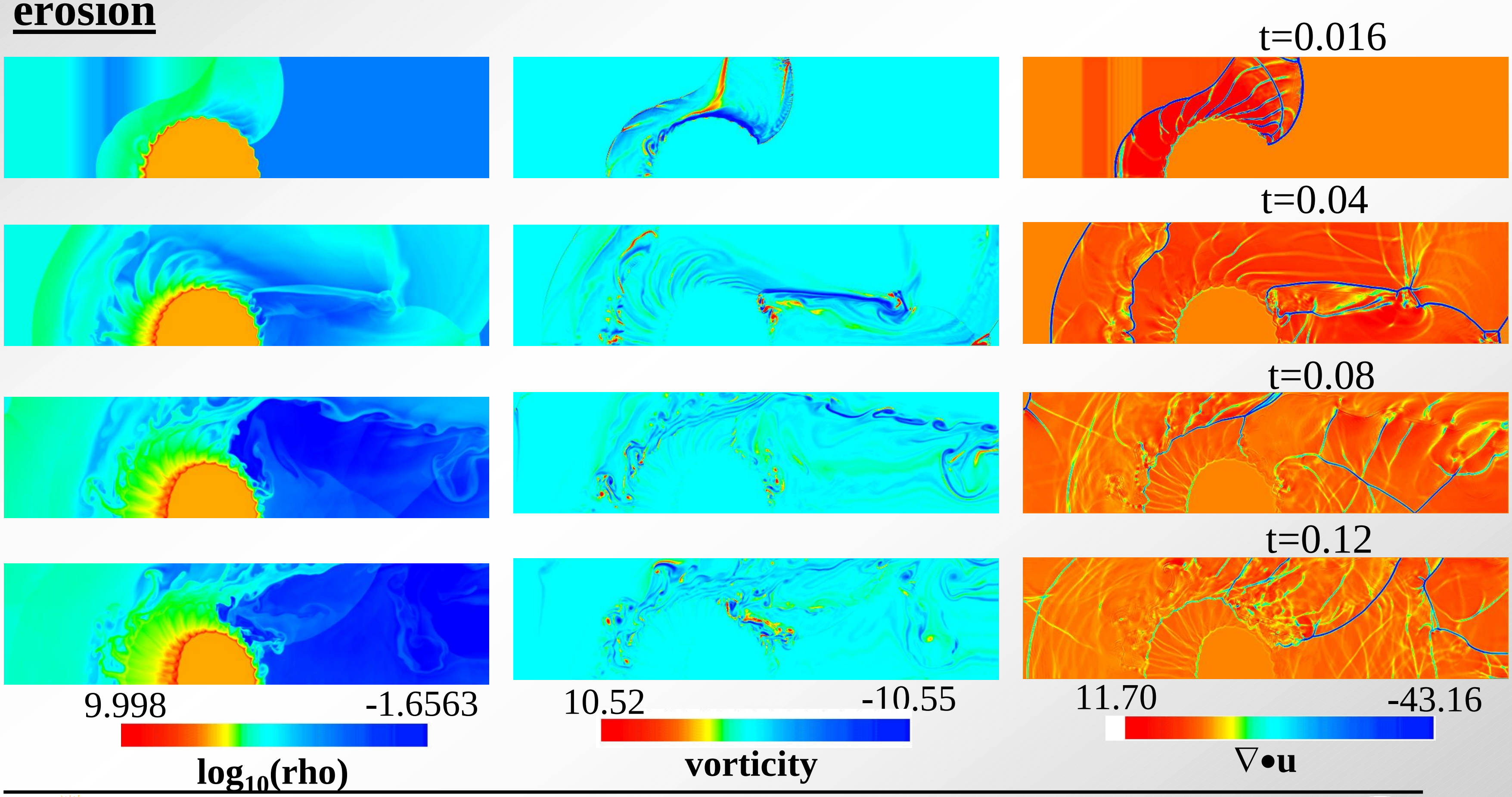


Fig. 5 Evolution of global circulation (positive, negative and sum integrated over the whole domain), t=0.01 corresponds approximately 4 years

S. Zhang et al, 12/12/2001

Simulation Snapshots I: Early time, juxtaposition of density (log scale), vorticity and div(u), vortex double layers, vortex projectiles, and upstream erosion

Part I: Simulations Cont.



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Upstream Erosion:

Part I: Simulations Cont.

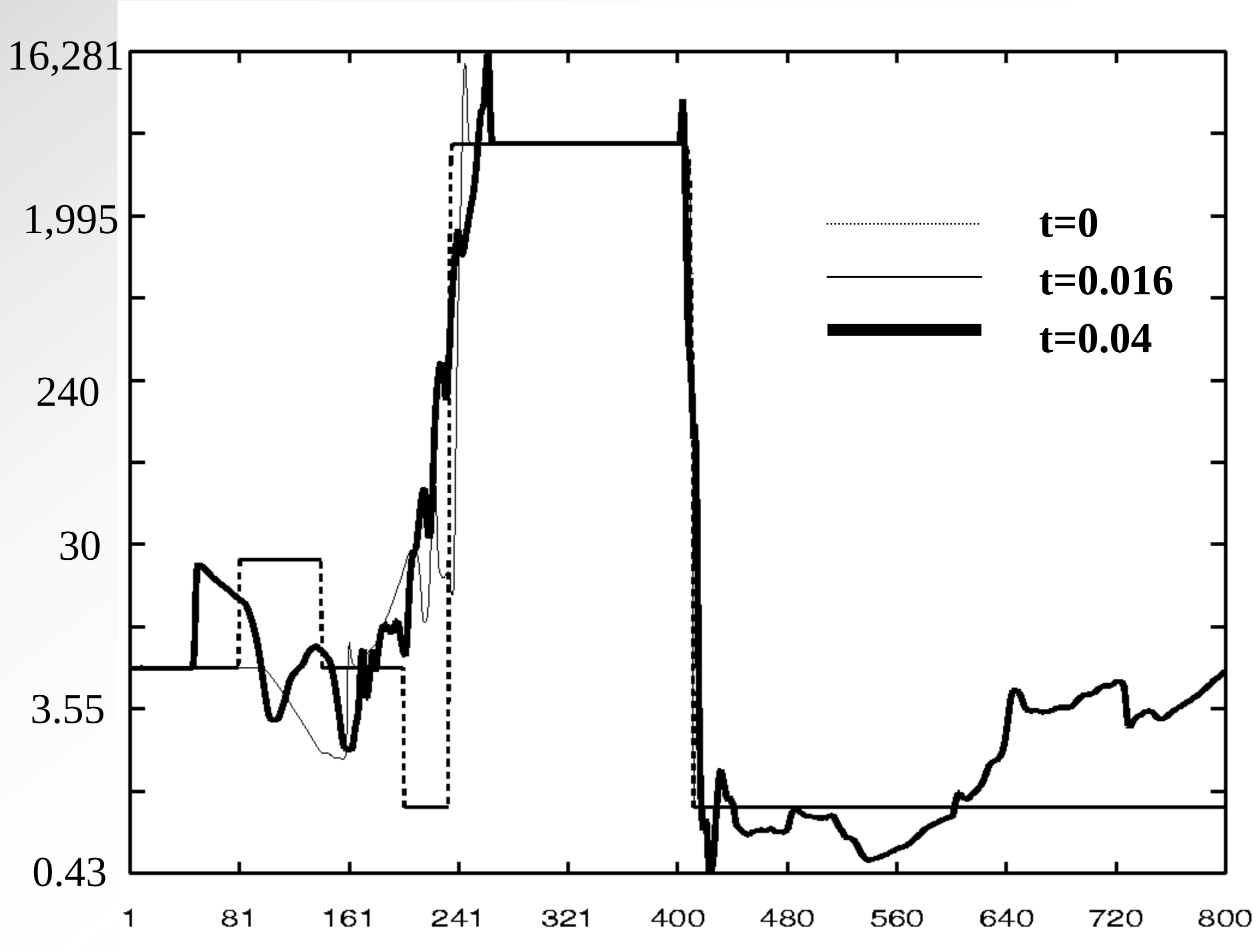
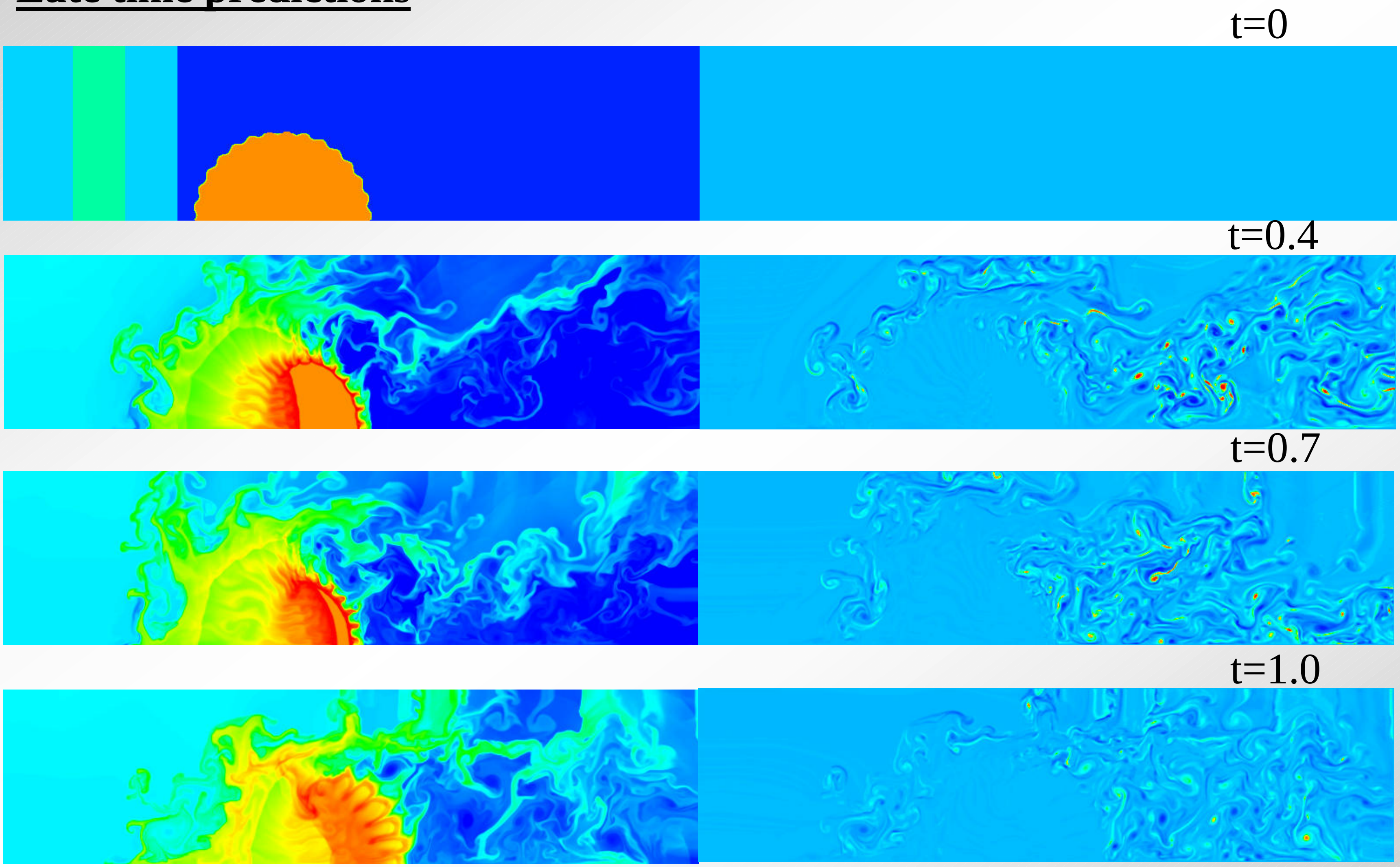


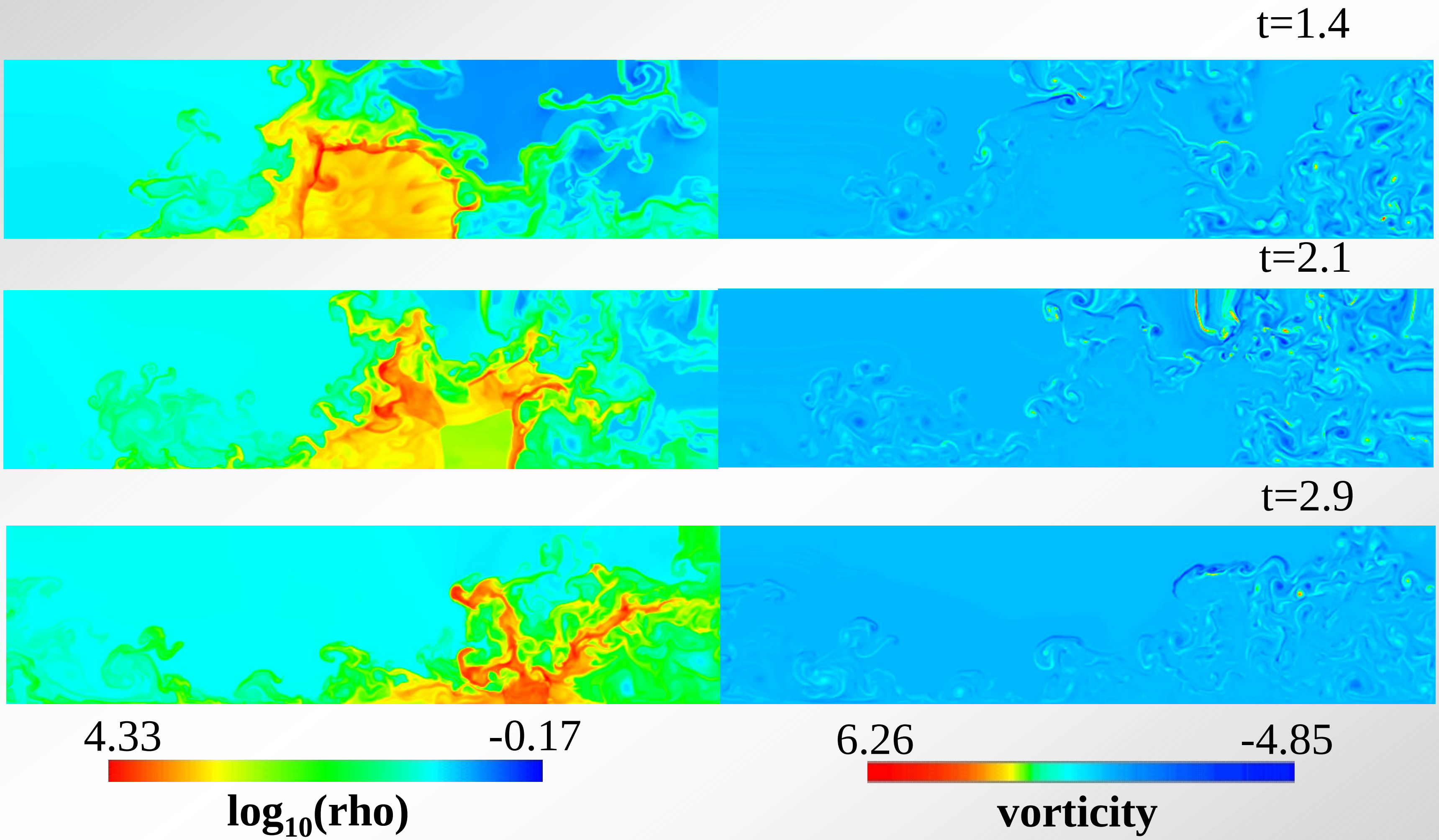
Fig. 6. Evolution of density (log scale) Slice at j=10

Late time predictions

Part I: Simulations Cont.



Part I: Simulations Cont.



Conclusions

1. We simulate a complex blast wave – cylindrical bubble interaction at M=66.77 and η=5000 with PPM;
2. We observe strong early time positive and negative circulation and vortex double layers due to complex blast wave structure;
3. We study the upstream erosion, which is consistent with [Borkowski et al 1997];
4. At intermediate time, we observe the primary vorticity deposition separates from the interface in an *elongated* vortex layer
5. We observe late time cavity collapse and re-expansion and corresponding fragmentation of the SN ring.