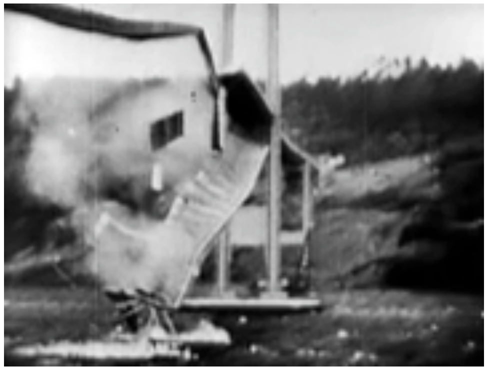
Acoustic-Mechanism Summary

Burrows, Livne, Dessart, Ott, Murphy 2006, ApJ, 640, 878
Burrows, Livne, Dessart, Ott, Murphy 2007, ApJ, 655, 416

Excitation (wind, walkers) -> Mechanical power (bridges)
Excitation (plucking) -> Acoustic power (musical instruments)

Tacoma Narrows bridge



Towards excitation of core g-modes, or *"the slow making of an engine"*

- Core bounce ($t = 0$ s)
- Shock stalls   ($t = 0.01 - 0.1$ s)
- PNS convection ($t > 0.1$ s)
- Convection behind shock ($t > 0.1$ s)
- SASI ($t > 0.2$ s)
- Core oscillations ($t > 0.5$ s)
- Acoustic power ($t > 1$ s)
- For late-time neutrino-driven wind without core-oscillations, see, e.g., VULCAN/2D simulations of AIC of white dwarfs (Dessart et al. 2006)

PNS Convection

(Dessart et al. 2006)

$$C_{\rm L}(r) = \left(\frac{\partial \rho}{\partial s}\right)_{Y_e,P}\frac{ds}{dr} + \left(\frac{\partial \rho}{\partial Y_e}\right)_{s,P}\frac{dY_e}{dr}$$

Ledoux criterion:

Unstable if >0

<0

Stabilizing if >0

< 0 for Y_e>0.2

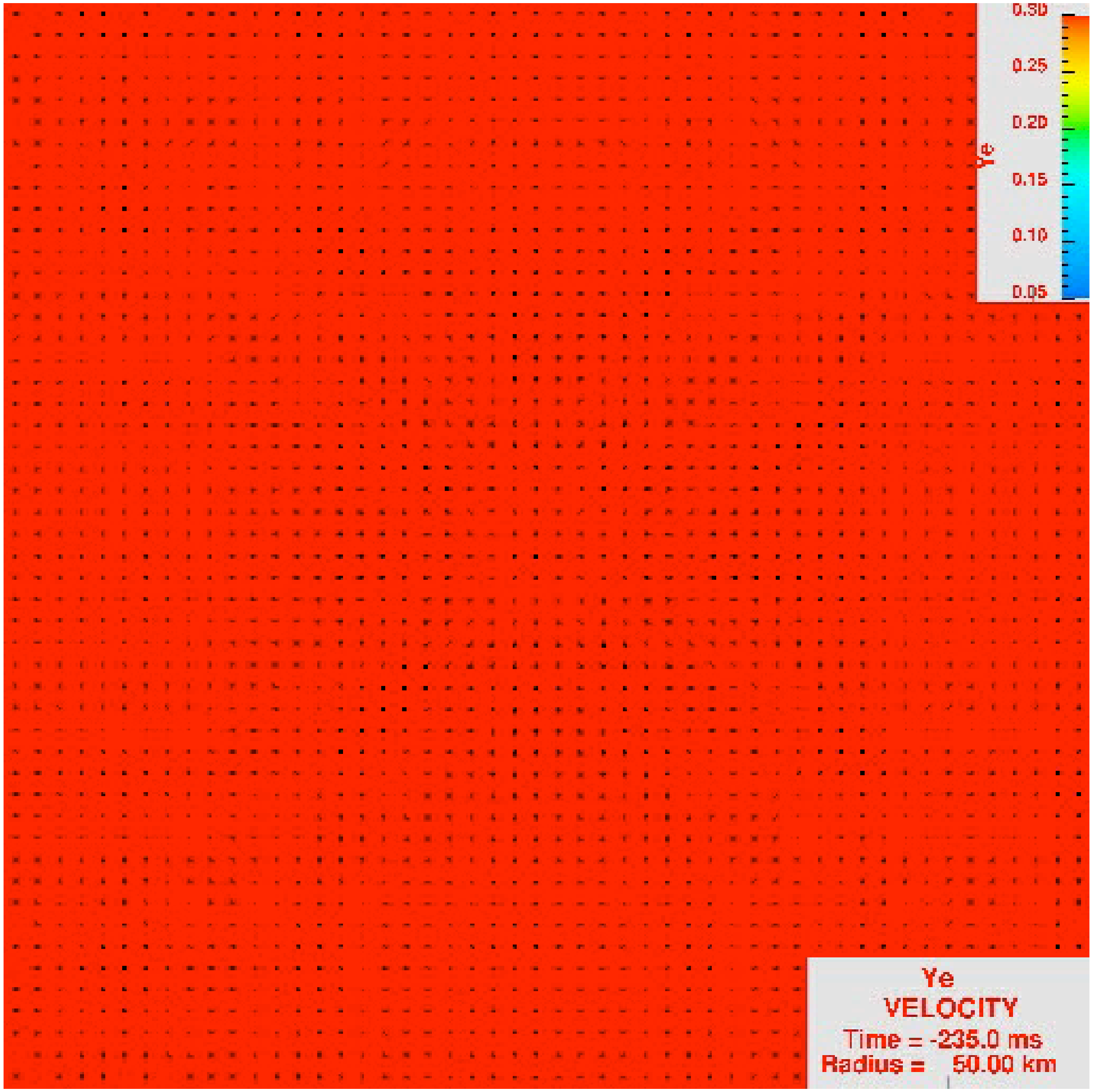
<0 in PNS => drives convection

1) **Advection** (accretion) modifies C_L

2) **Neutrino transport** smoothes Ye and s gradients on diffusive (long) time scales (Bruenn et al. 2005; Mezzacappa et al. 1998)

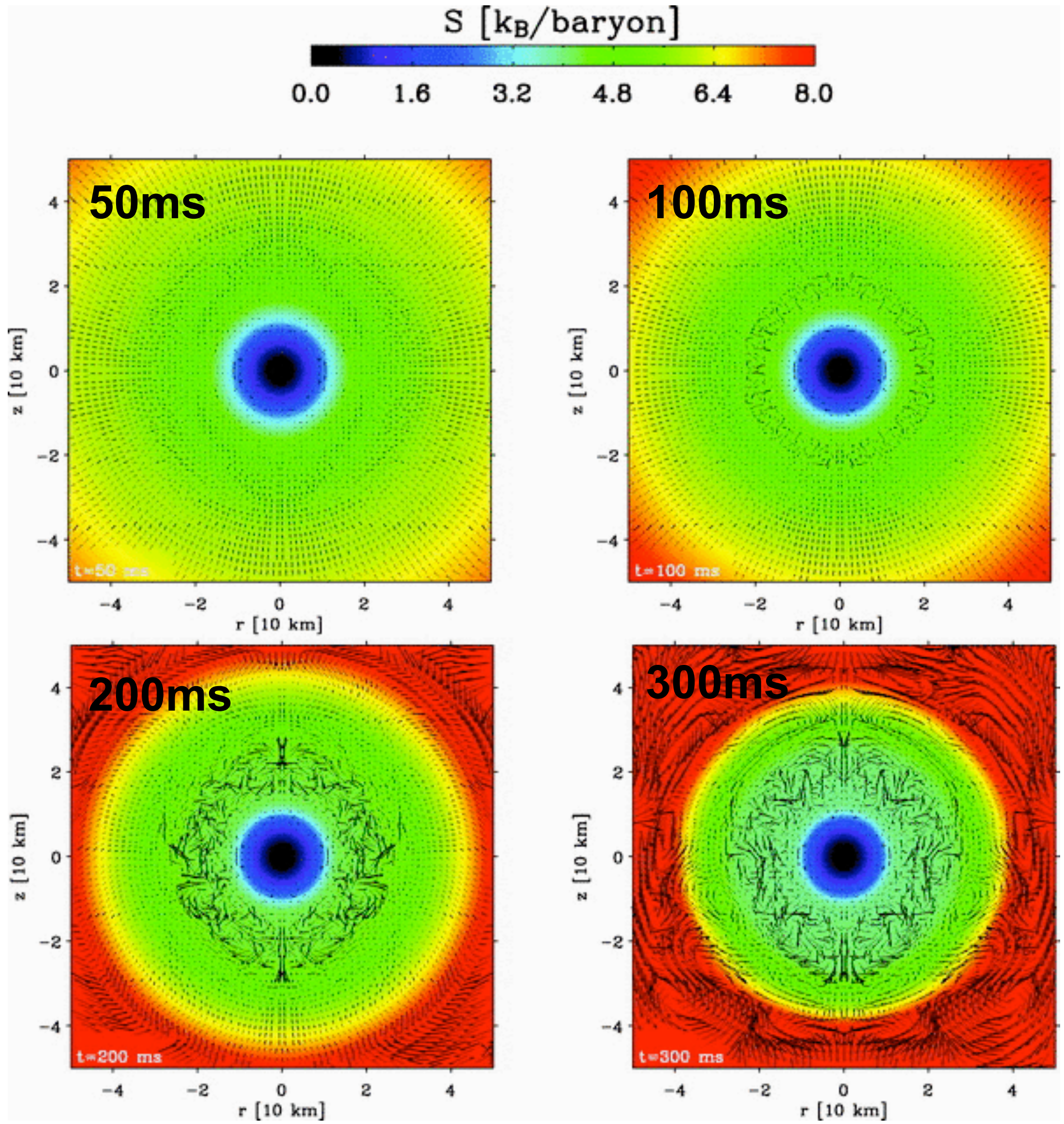
Note: **Different** from **entropy-driven** convection behind shock

PNS Convection



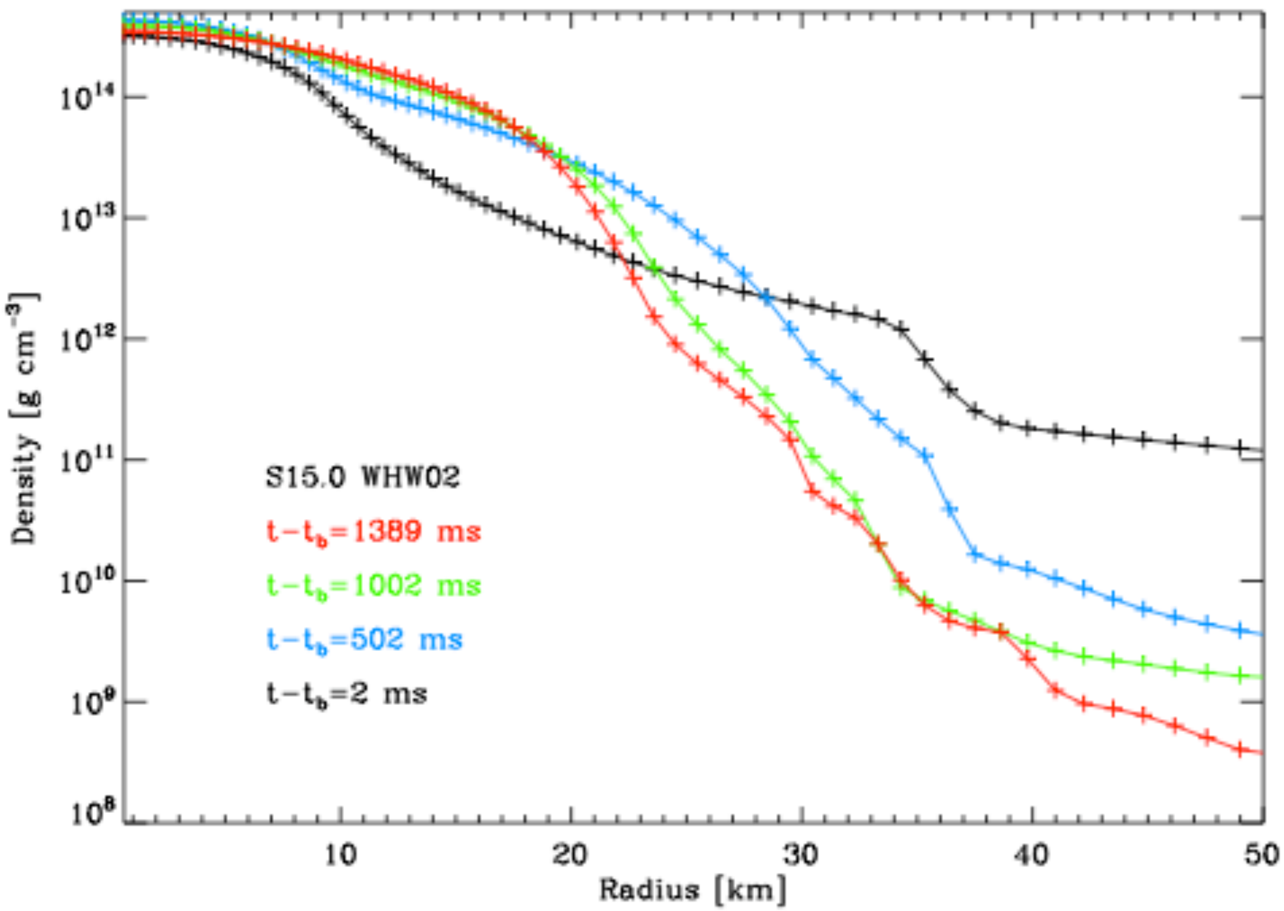
PNS Convection

- 11.2 M_{sun} model of Woosley, Heger, & Weaver 2002
- Transition Radius at 10 km
- Horns at 7 km (< R_{shock} formation)
- Courant time step: 0.3μs
- Well-resolved convection between 10-20 km
- Gravity waves at PNS surface
- PNS convection does not prevent late-time excitation of core oscillations!



Density Profile at selected times

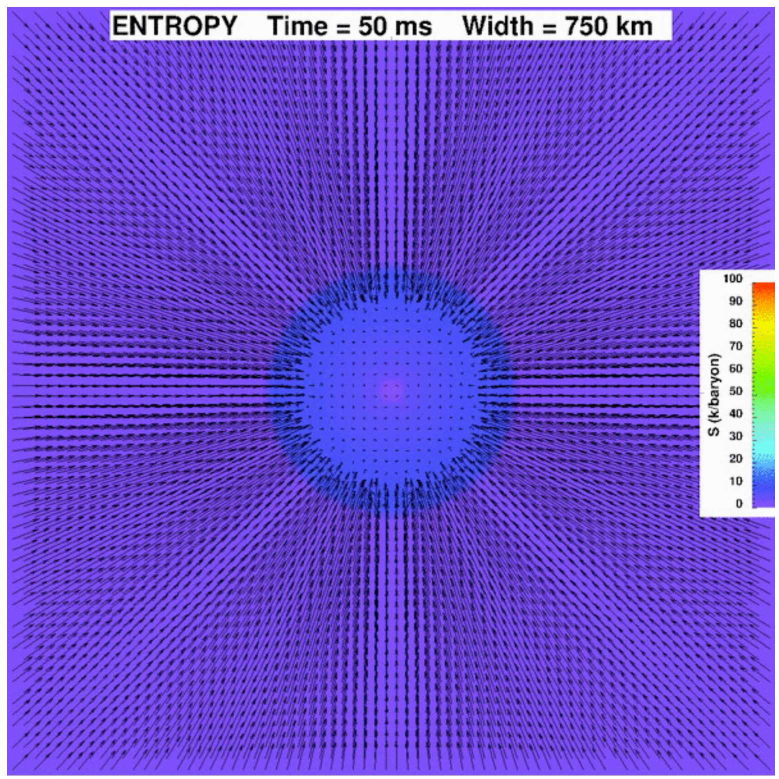
About 5 points per decade in density at (very) late times

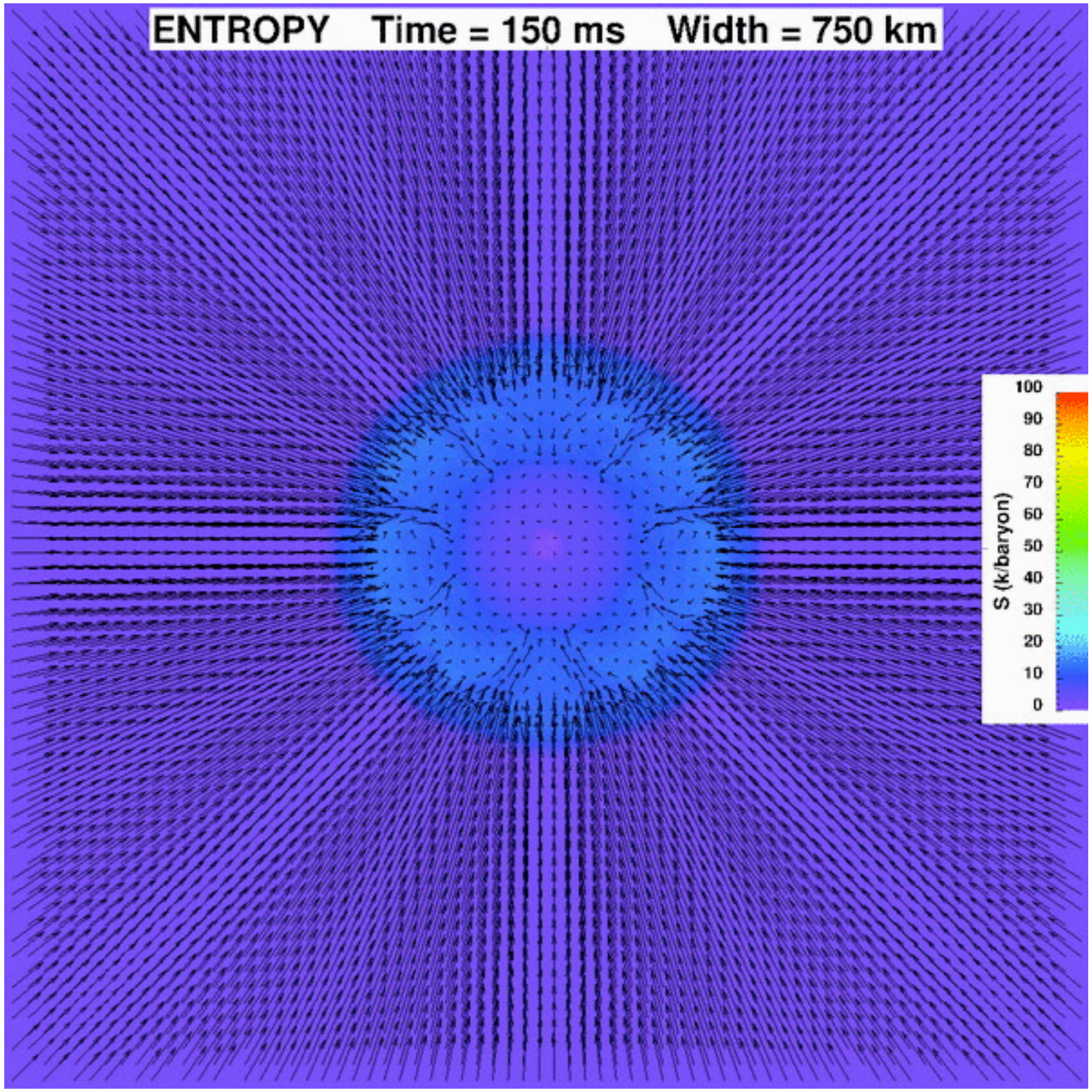


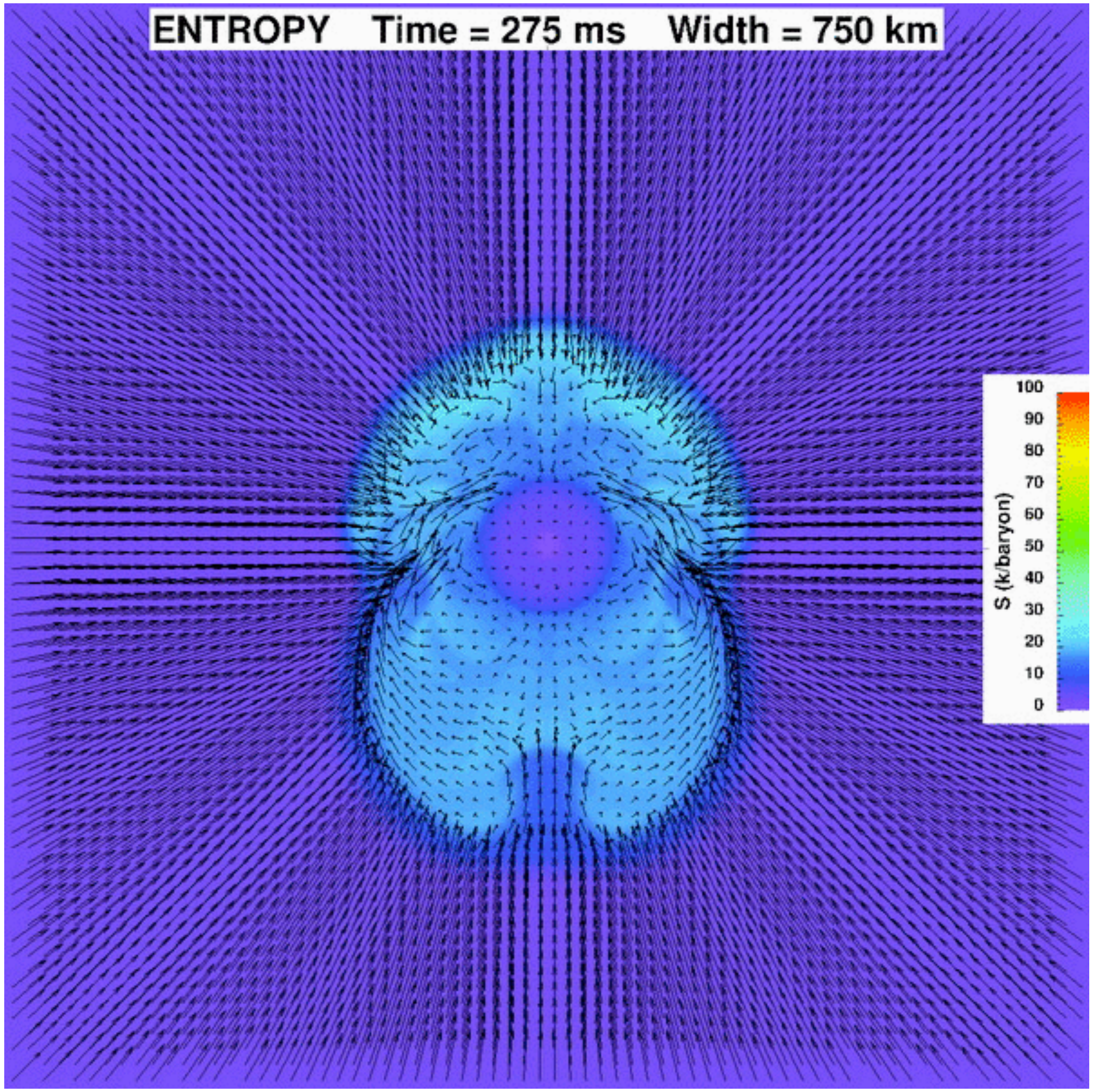
Chronology of events

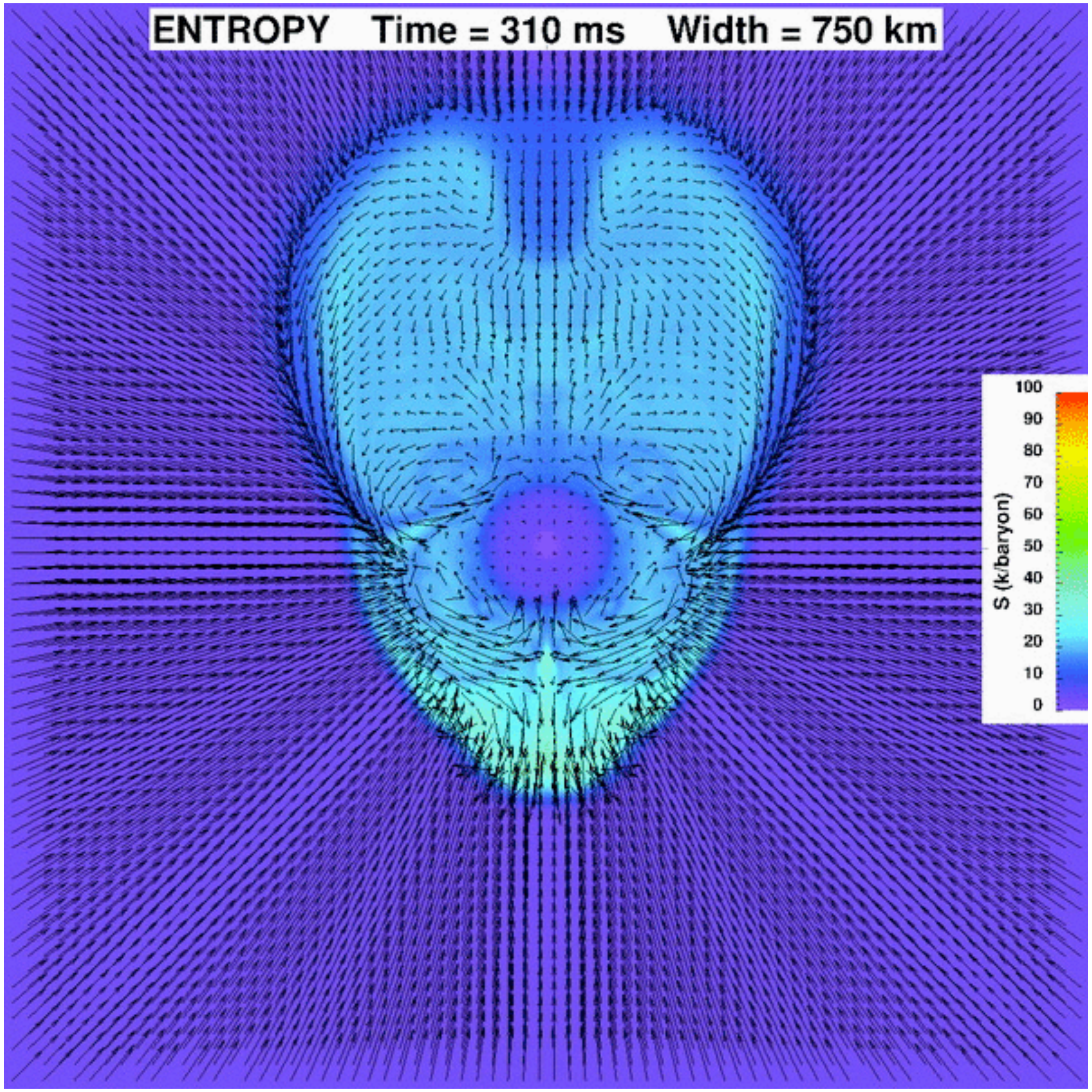
(Burrows et al. 2006)

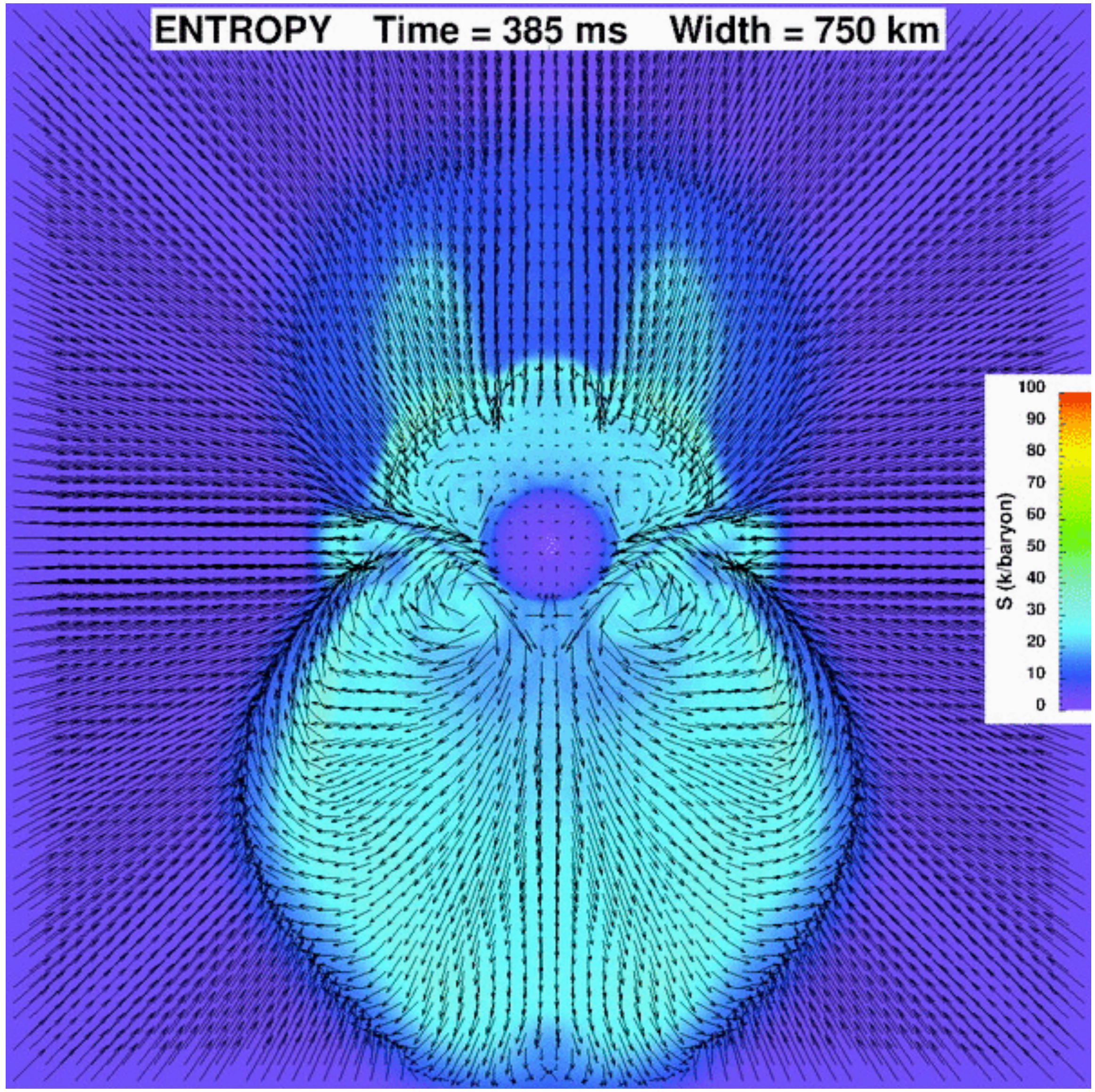
- 11M_{sun} model of Woosley & Weaver (1995)
- R_{max} = 3800km; R_t = 30 km
- 180^o axi-symmetric slice; 120 θ angles
- 16 ε_ν and 3 neutrino flavors

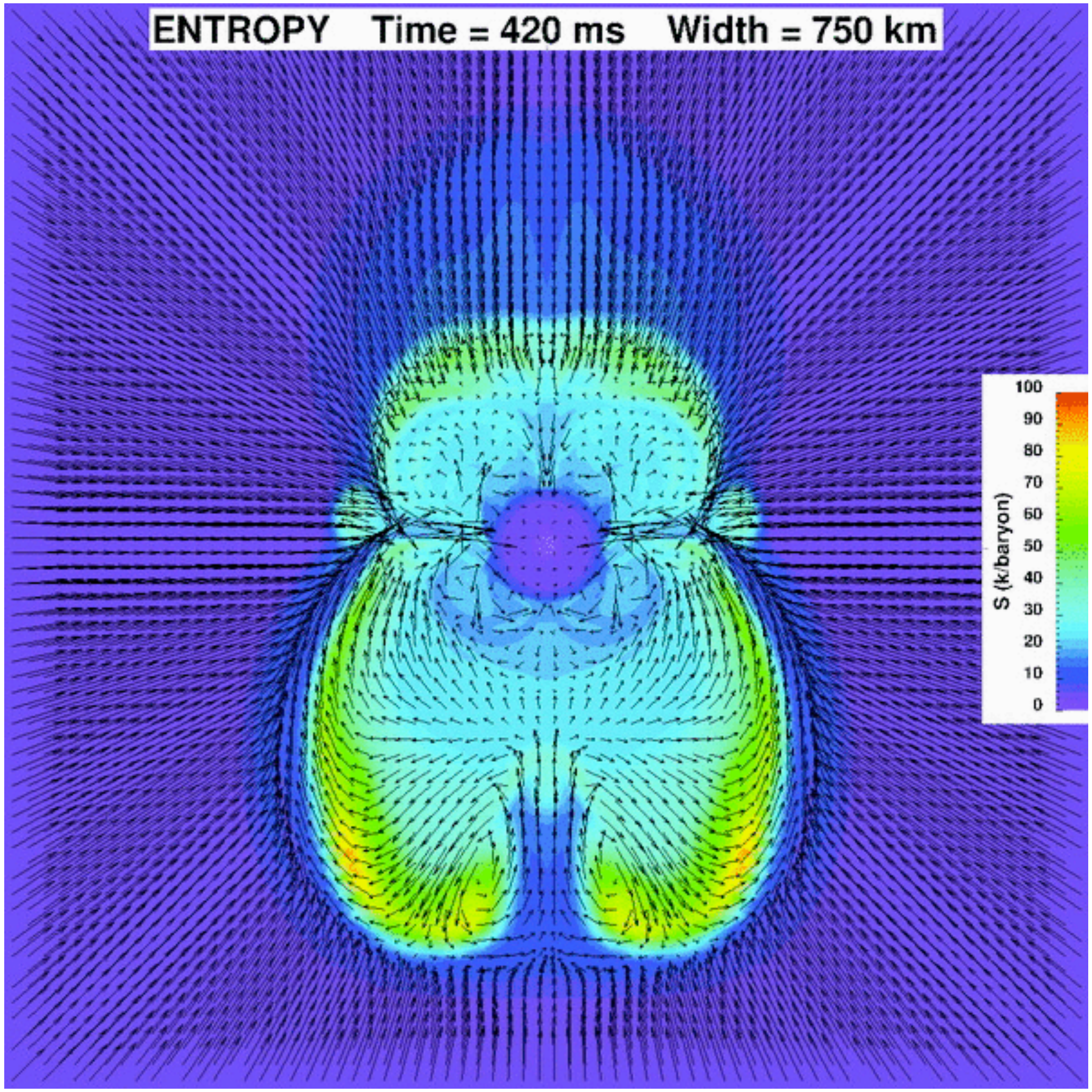


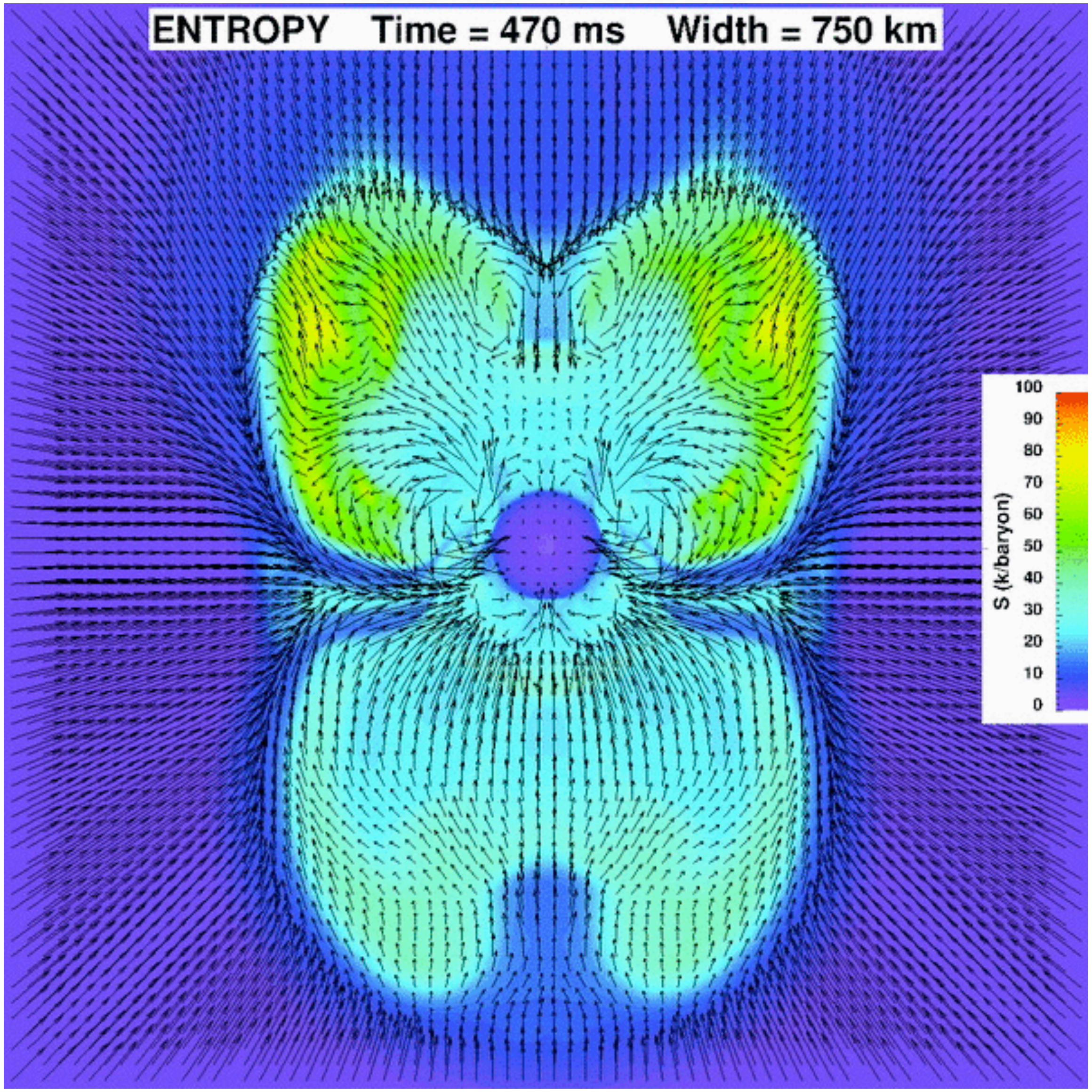

ENTROPY Time = 150 ms Width = 750 km
S (k/baryon)
100
90
80
70
60
50
40
30
20
10
0

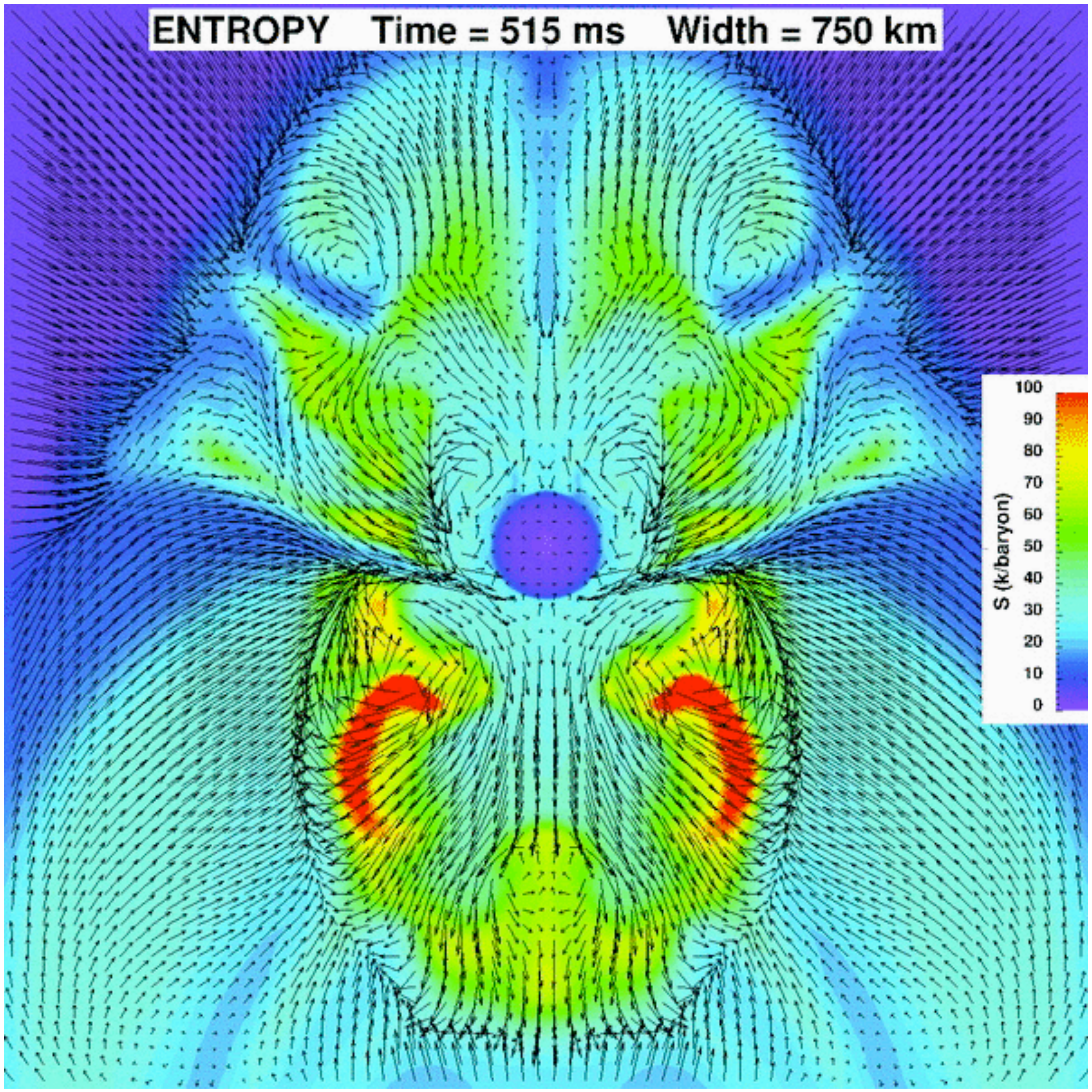

ENTROPY Time = 275 ms Width = 750 km
S (k/baryon)
100
90
80
70
60
50
40
30
20
10
0

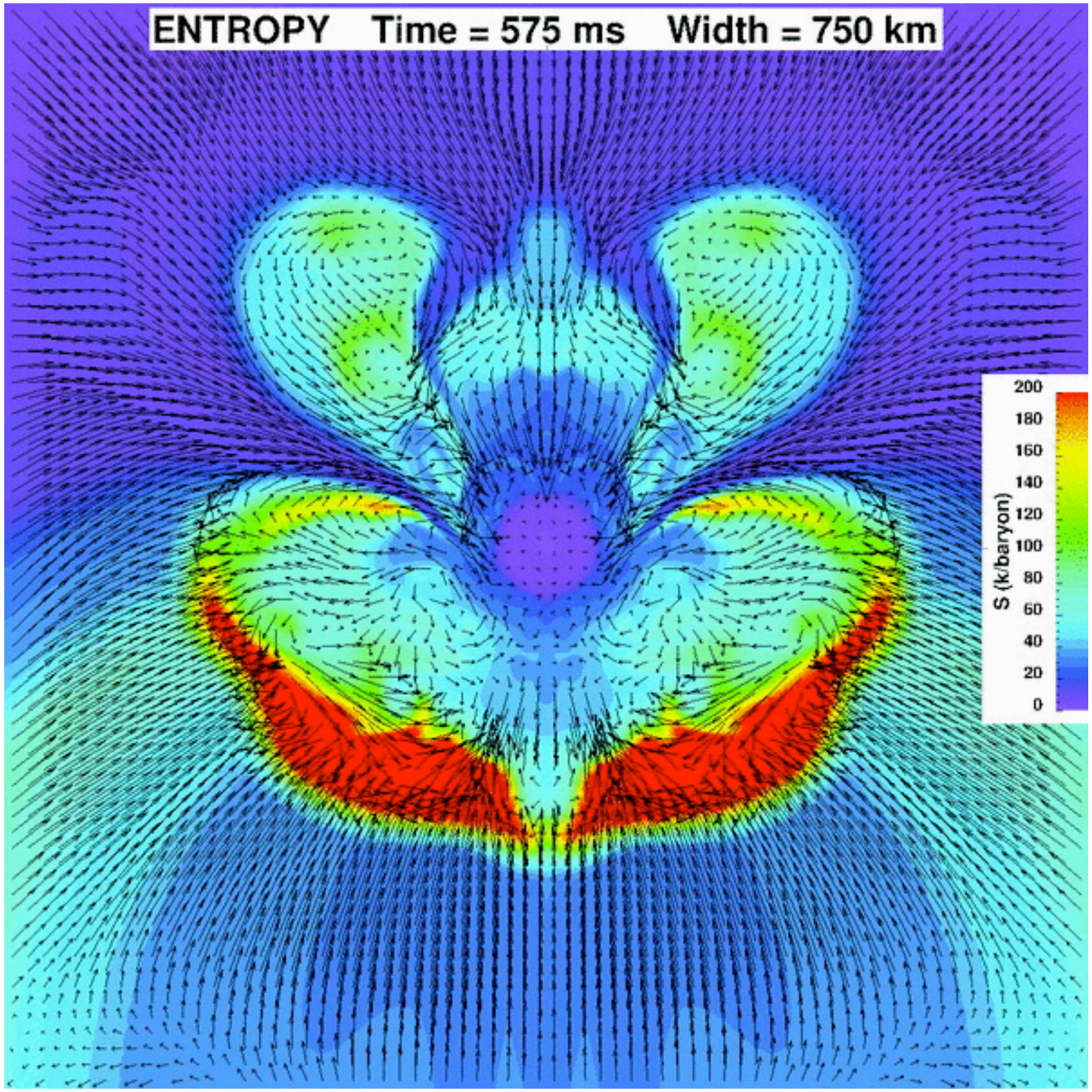

ENTROPY Time = 310 ms Width = 750 km
S (k/baryon)
100
90
80
70
60
50
40
30
20
10
0

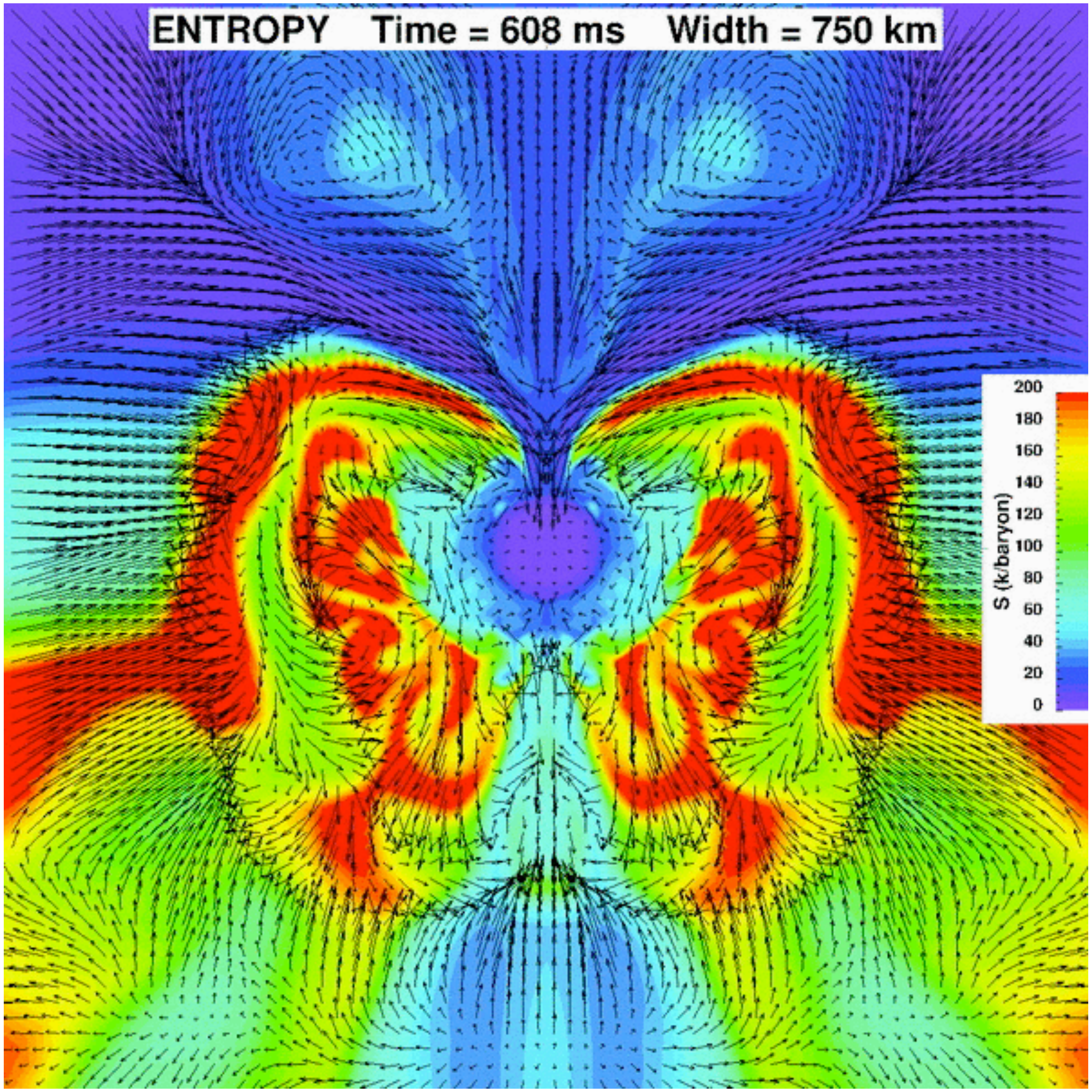

ENTROPY Time = 385 ms Width = 750 km
S (k/baryon)
100
90
80
70
60
50
40
30
20
10
0


ENTROPY Time = 420 ms Width = 750 km
S (k/baryon)
100
90
80
70
60
50
40
30
20
10
0

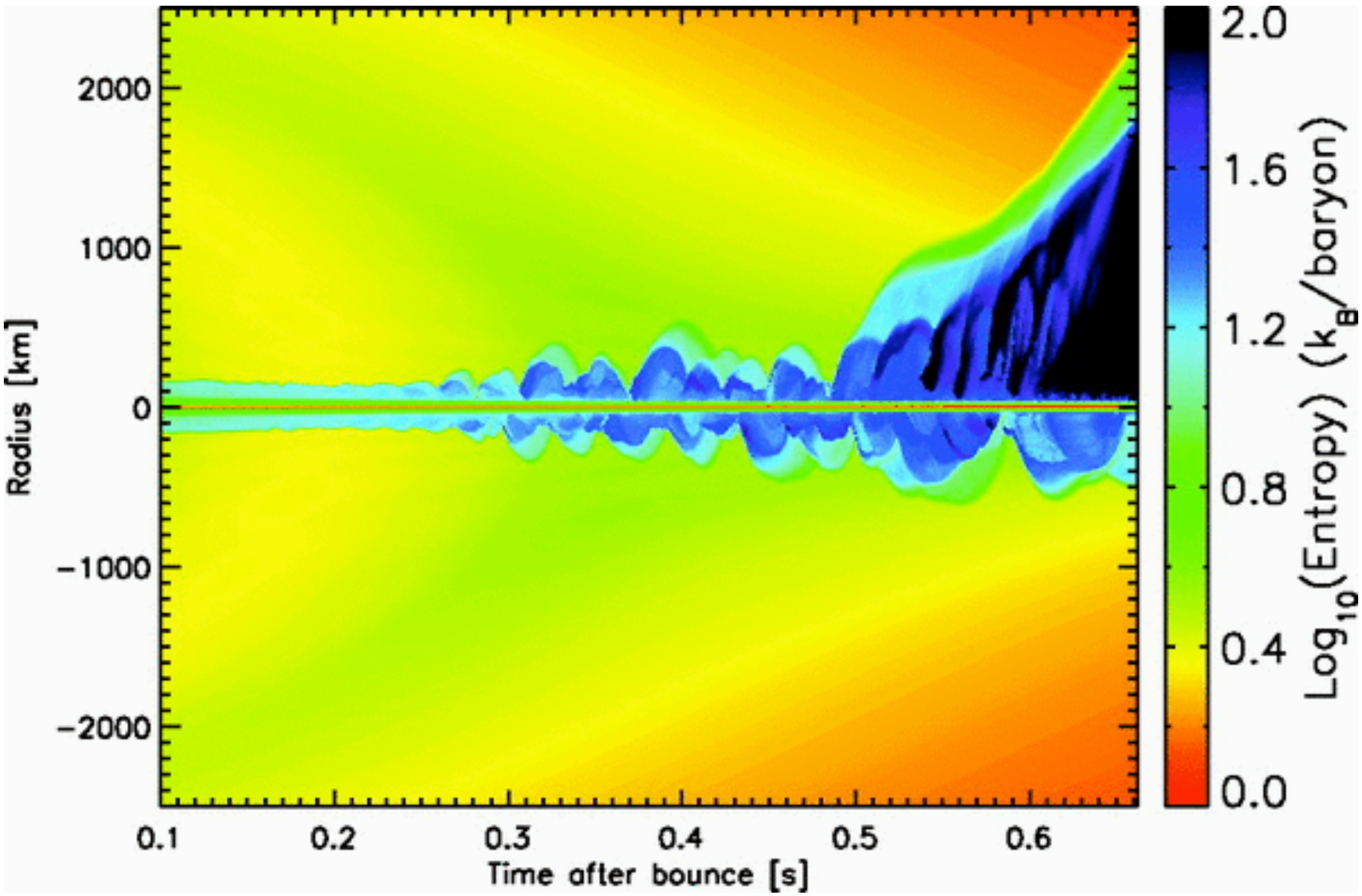

ENTROPY Time = 470 ms Width = 750 km
S (k/baryon)
100
90
80
70
60
50
40
30
20
10
0


ENTROPY Time = 515 ms Width = 750 km
S (k/baryon)
100
90
80
70
60
50
40
30
20
10
0

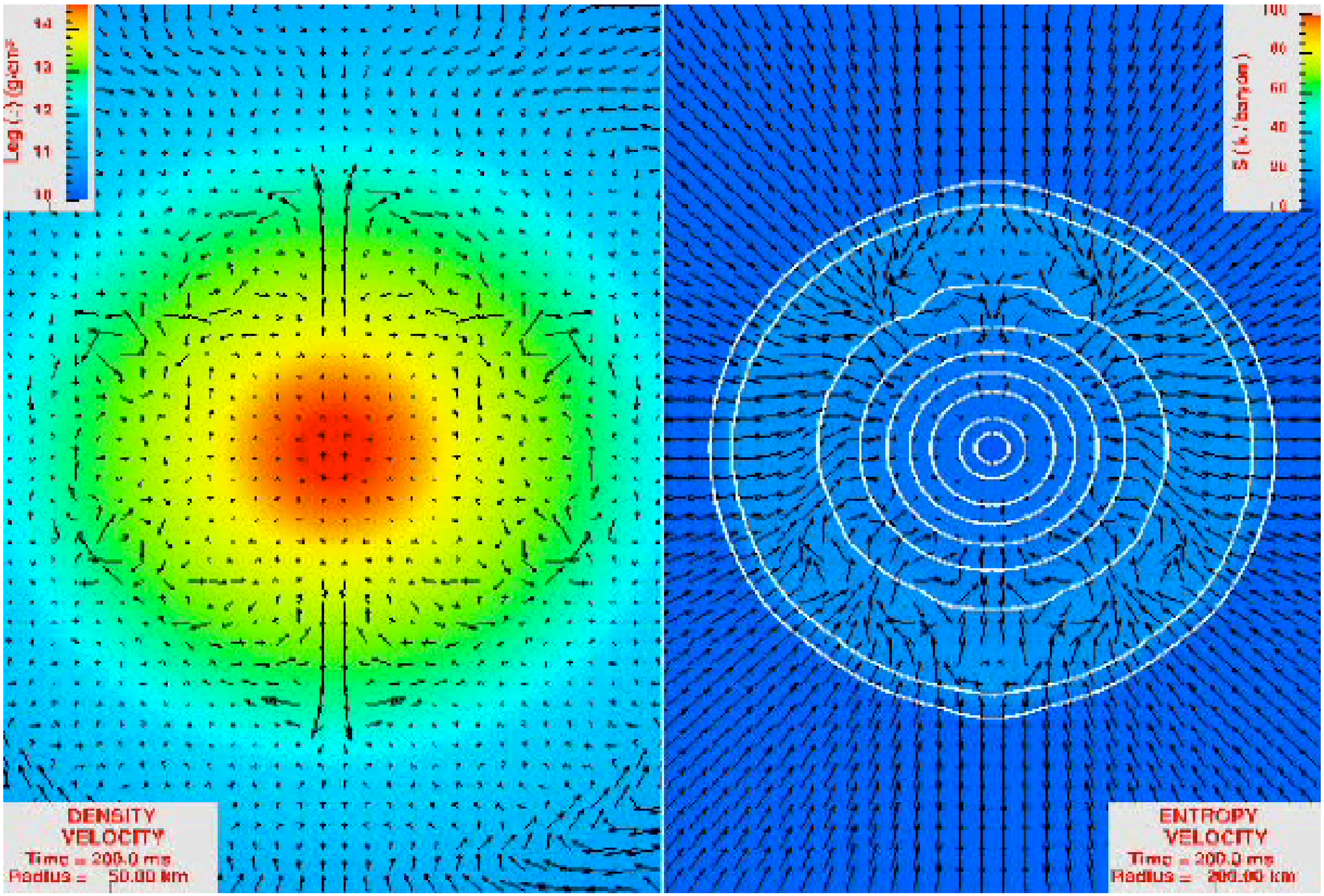

ENTROPY Time = 575 ms Width = 750 km
S (k/baryon)
200
180
160
140
120
100
80
60
40
20
0


ENTROPY Time = 608 ms Width = 750 km
S (k/baryon)
200
180
160
140
120
100
80
60
40
20
0

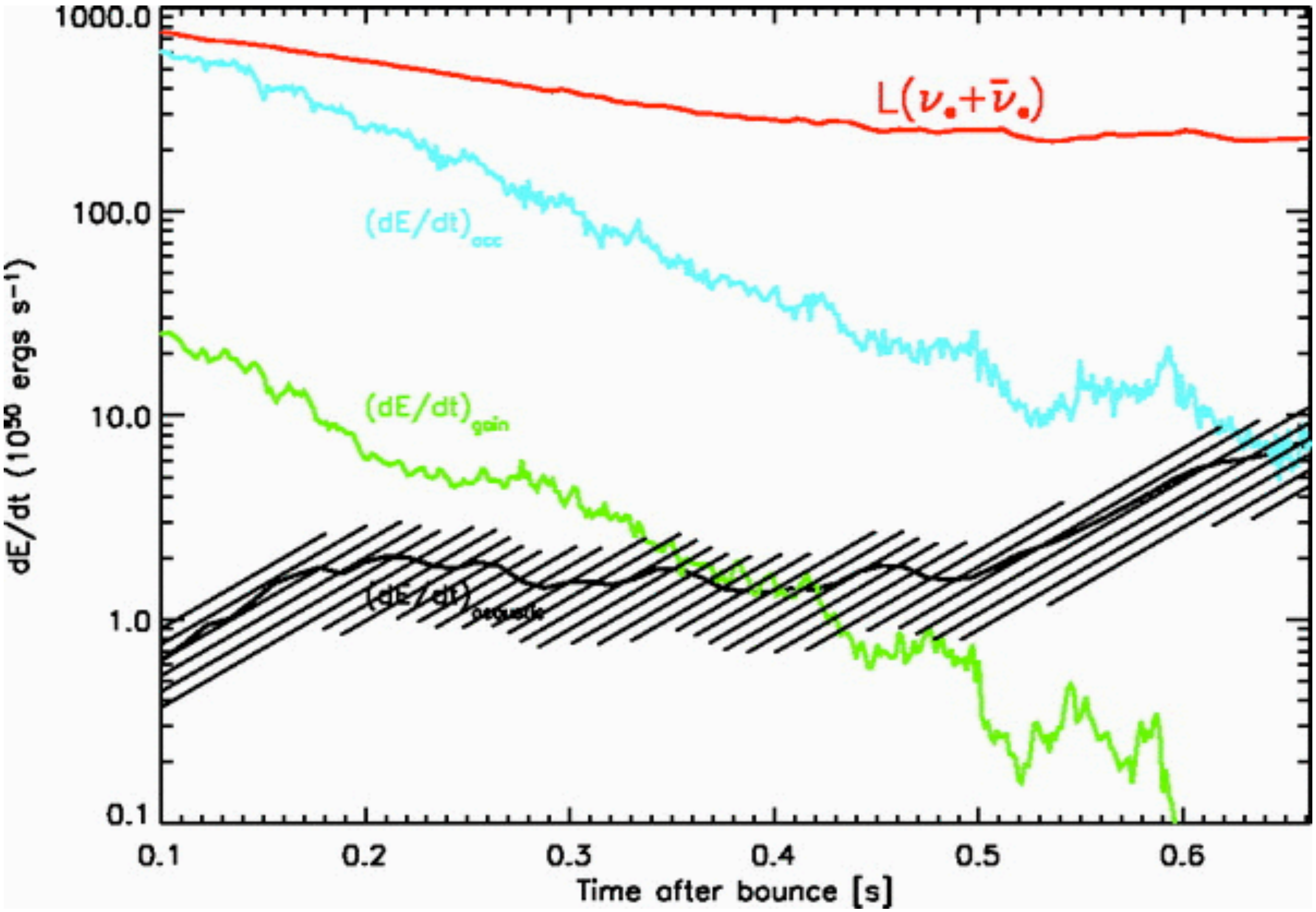
Time Evolution of the Entropy along North/South poles



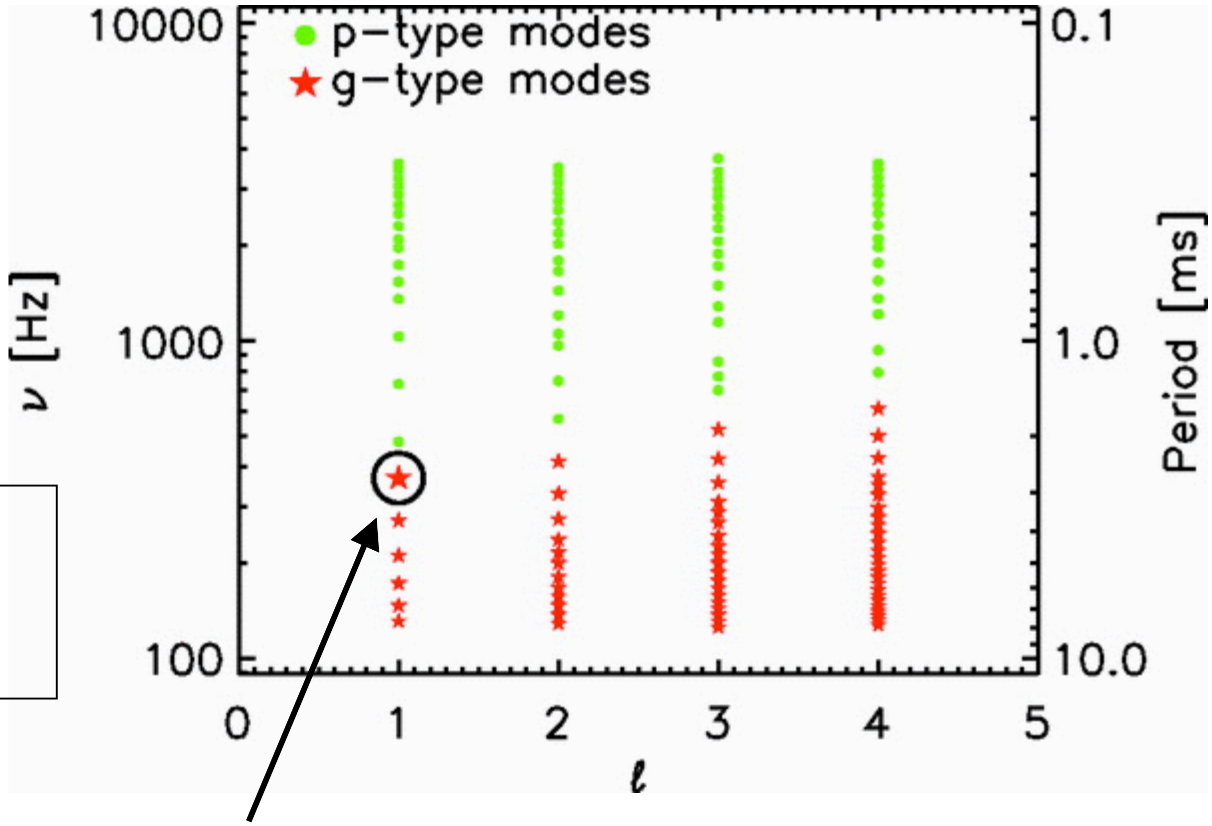
Core-Oscillations



Acoustic Power versus Neutrino net gain



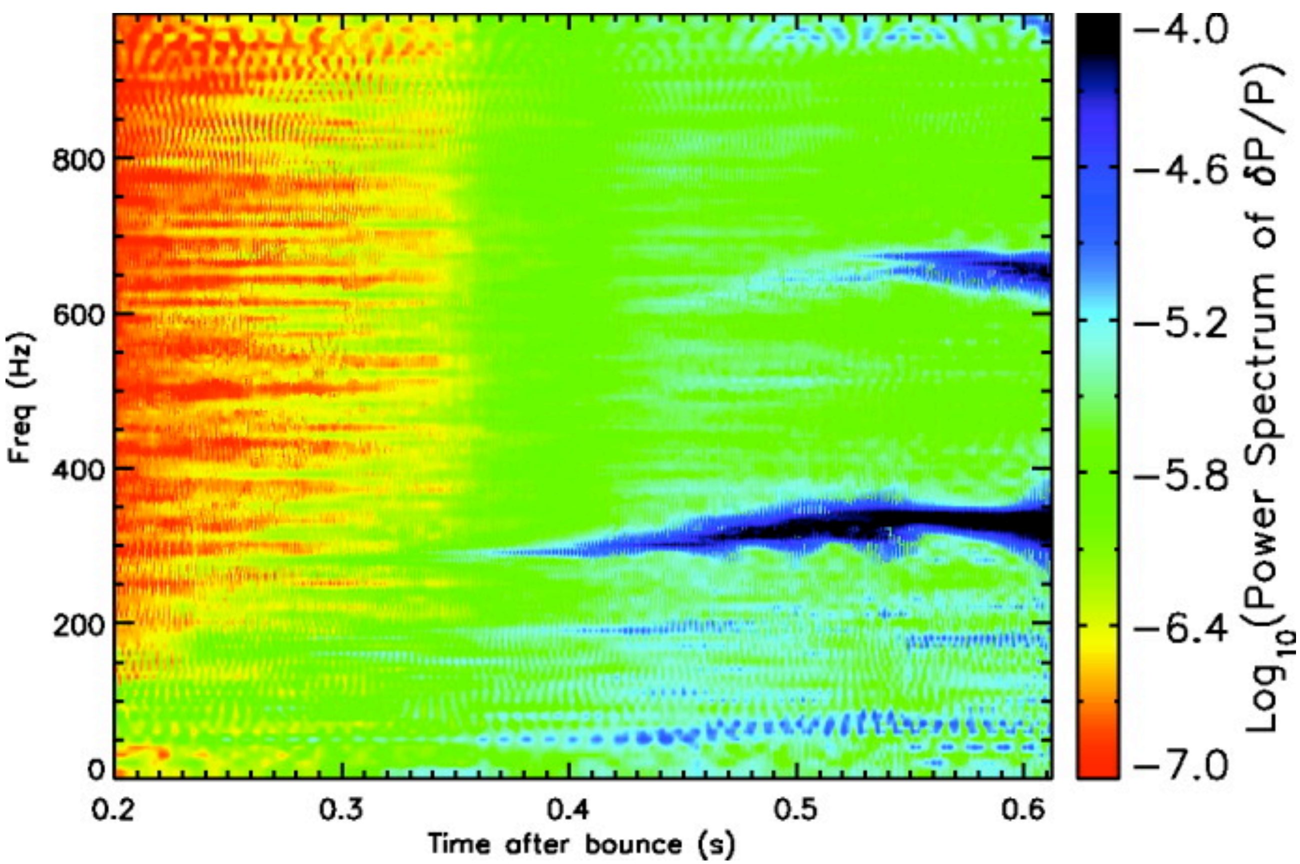
Frequency versus spherical-harmonic l for the analytic core g and p modes



Pulsational analysis for sphericized PNS *(J. Murphy)*

Mode with predominantly g-mode character that has been most easily excited in our simulation.

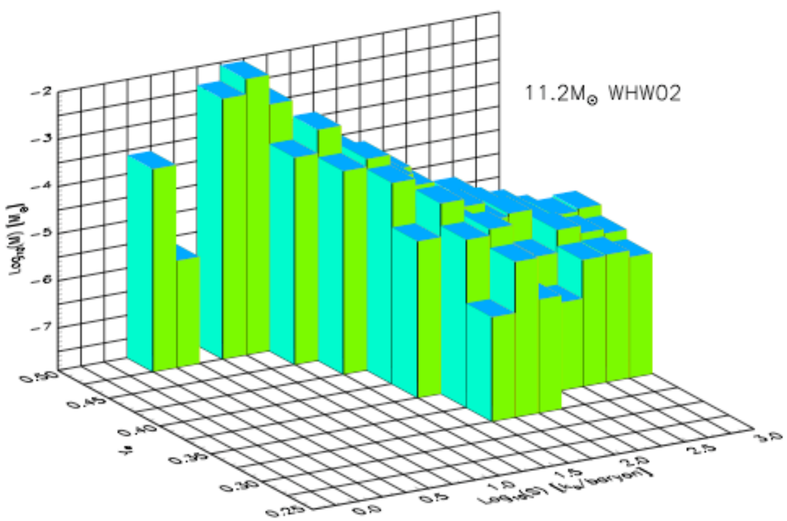
Pressure Fluctuations at 35km
(Burrows et al. 2006)

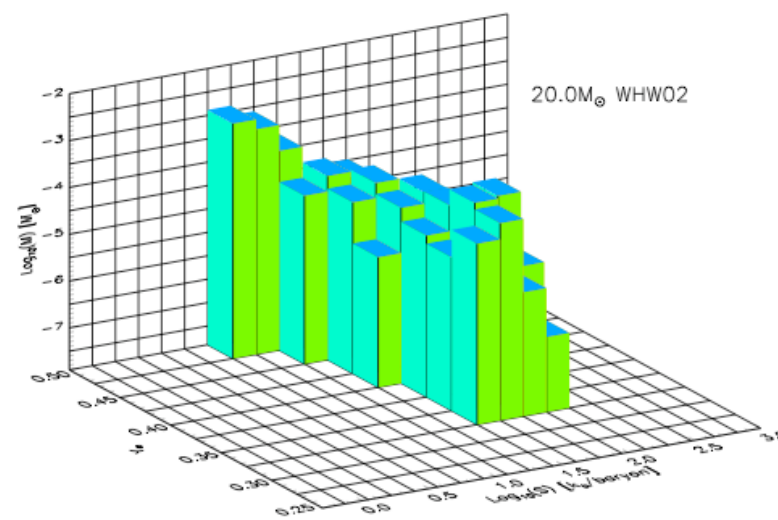


r-process Nucleosynthesis
(low-Y_e/high-Entropy Material)

Model s11.2_whw02
M_{tot} ejecta: 0.0191 M_{sun}
($0.0002M_{sun}$ above $S=100k_b$/baryon)

Model s20.0_WHW02
M_{tot} ejecta: 0.0041 M_{sun}
($0.00001M_{sun}$ above $S=100k_b$/baryon)





Criticisms on acoustic mechanism

- Parametric instability: Can one mode take the whole share of the cake? (Weinberg & Quataert 2008). Resolution?
- Numerical problems (gravity solver, momentum conservation)
- Maximum amplitude of g-mode at r=z=0km => difficult to grasp if material at r=z=0 is at rest by design
- Neutrino mechanism occurs earlier? Acoustic mechanism needs t >0.5 -1 s to reach interesting powers
- Are acoustic powers viable, i.e. 10^{51} erg/s sustained for one second?
- Tendency to over-emphasize differences rather than common results….
- Are core-collapse SN explosions triggered early in Nature?
- Need for observations to constrain mechanism (GRW, neutrino signatures), rather than just numerical arguments