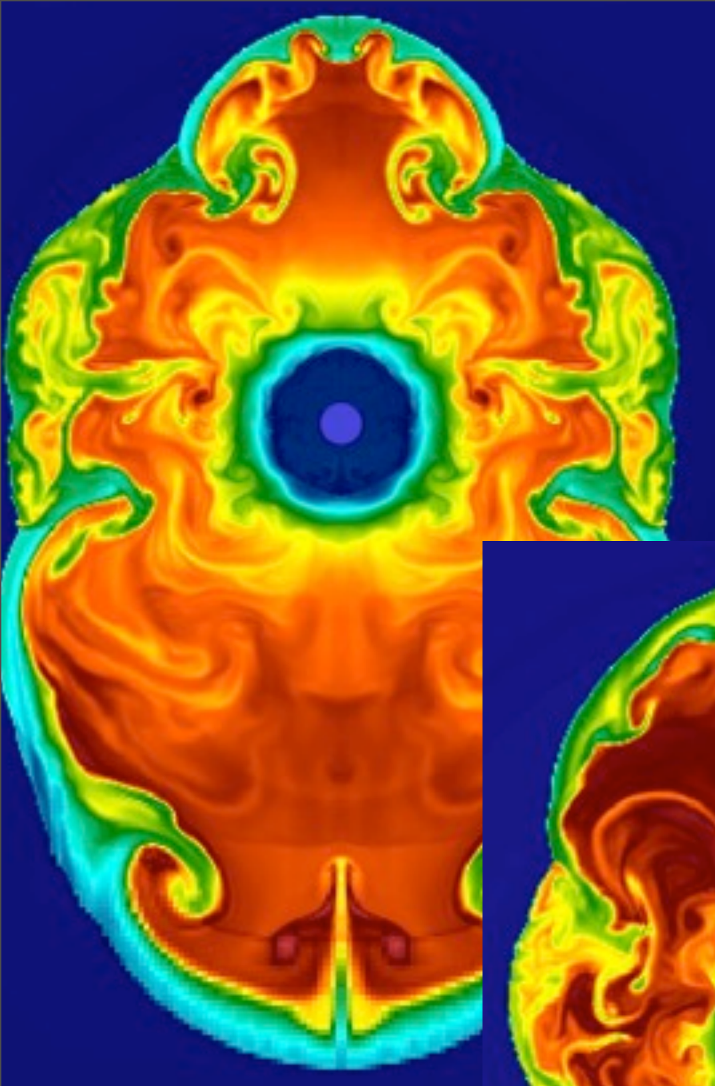
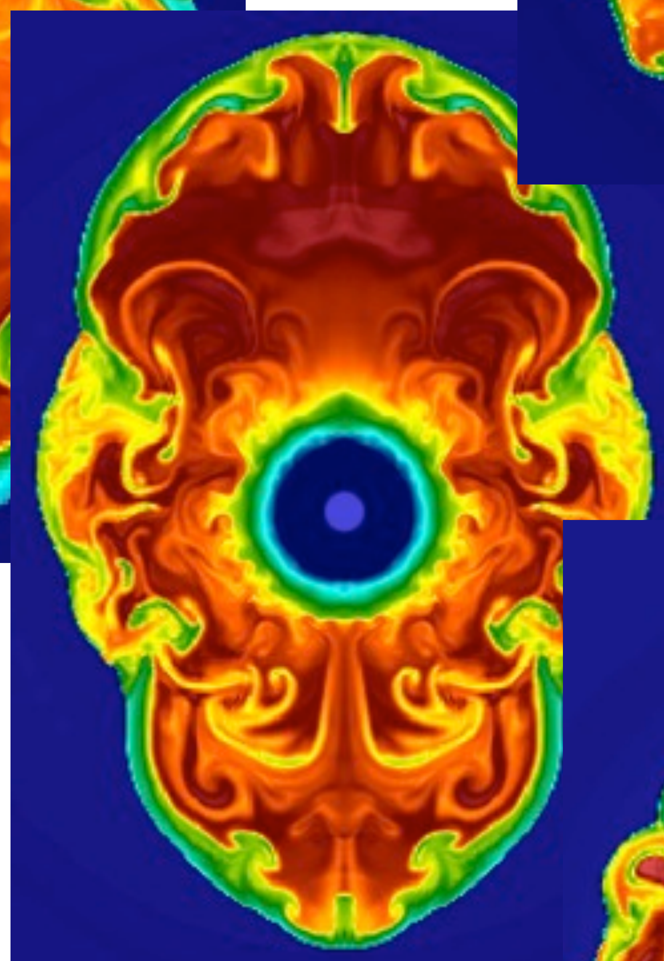
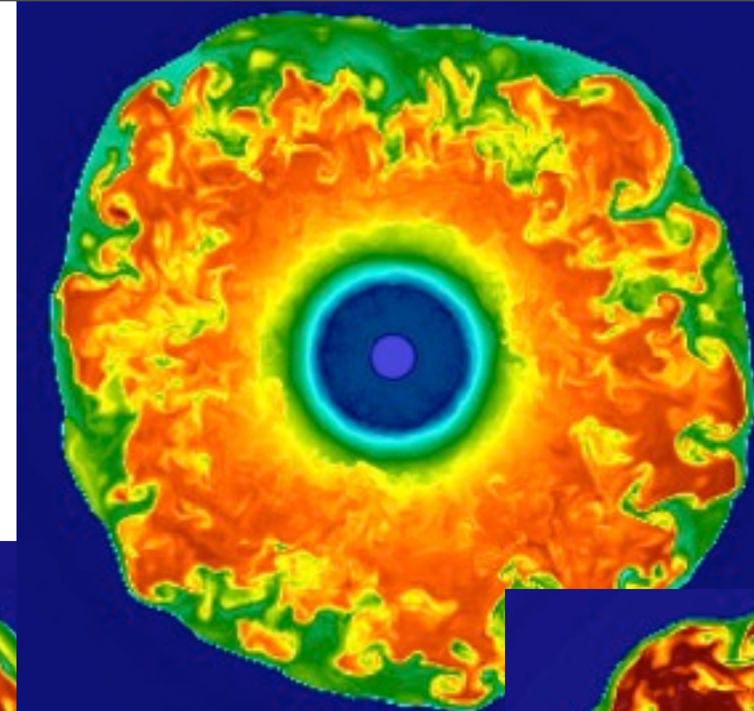
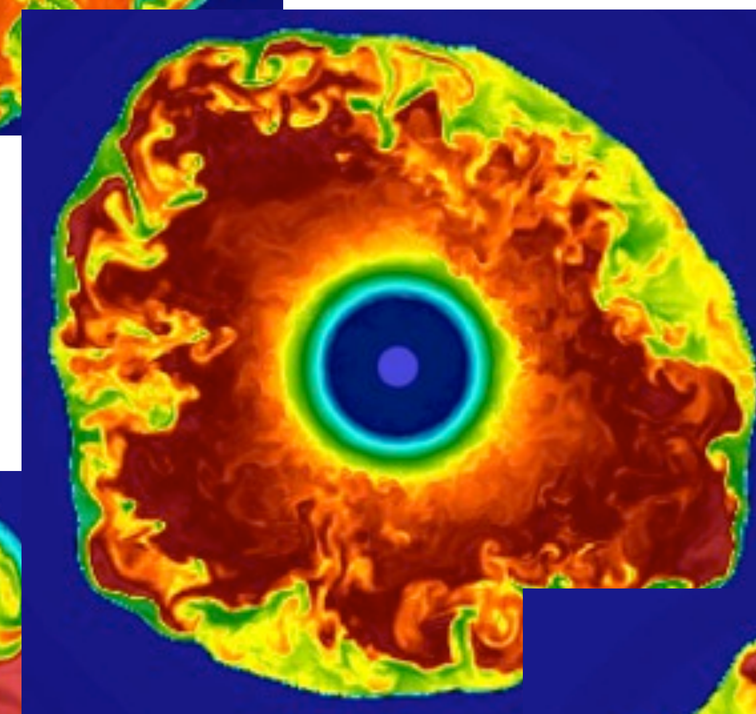
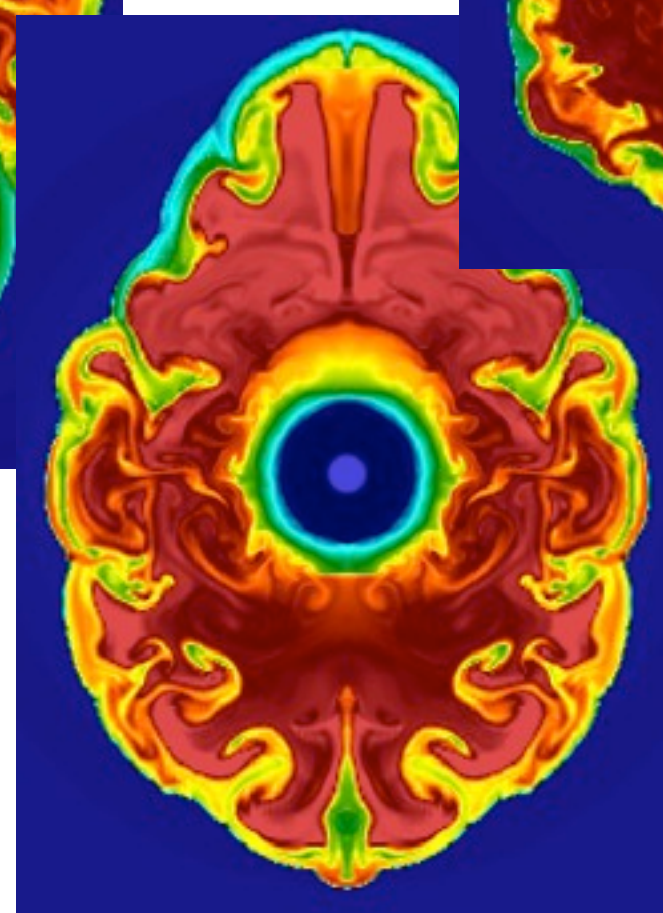
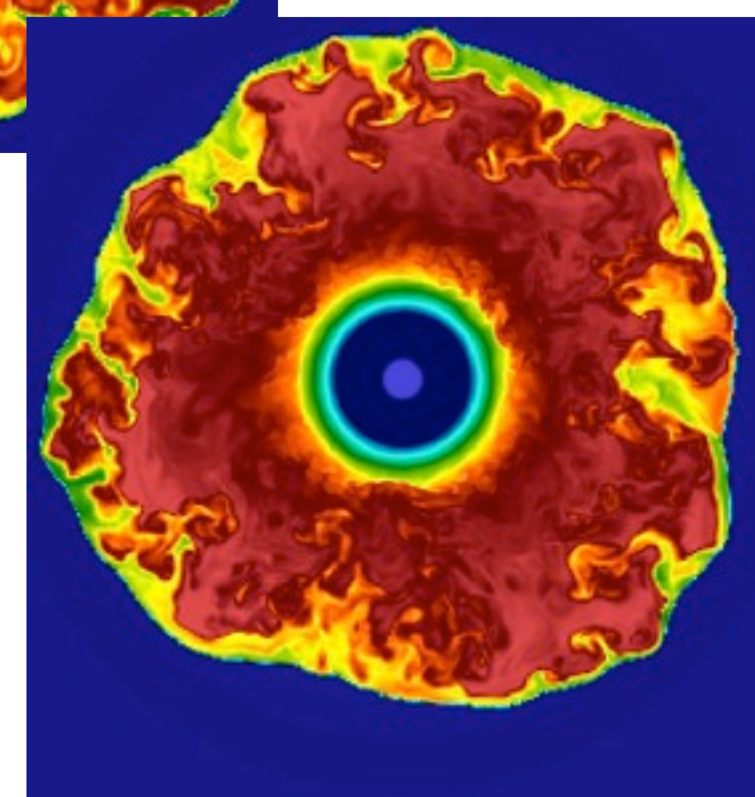




# Multidimensional Hydrodynamics of Core-Collapse Supernovae

Josh Dolence, Princeton

with
Adam Burrows
&
Jeremiah Murphy

# A Multidimensional History

Time

- 1979 Lepton-gradient-driven convection (e.g. Epstein)
- 1985 Neutron fingers (e.g. Wilson)
- 1987 Prompt convection (e.g. Burrows)
- 1990 Neutrino-driven convection (e.g. Bethe)
- 2003 Standing Accretion Shock Instability (Blondin et al.)
- Now Neutrino-driven convection & the SASI

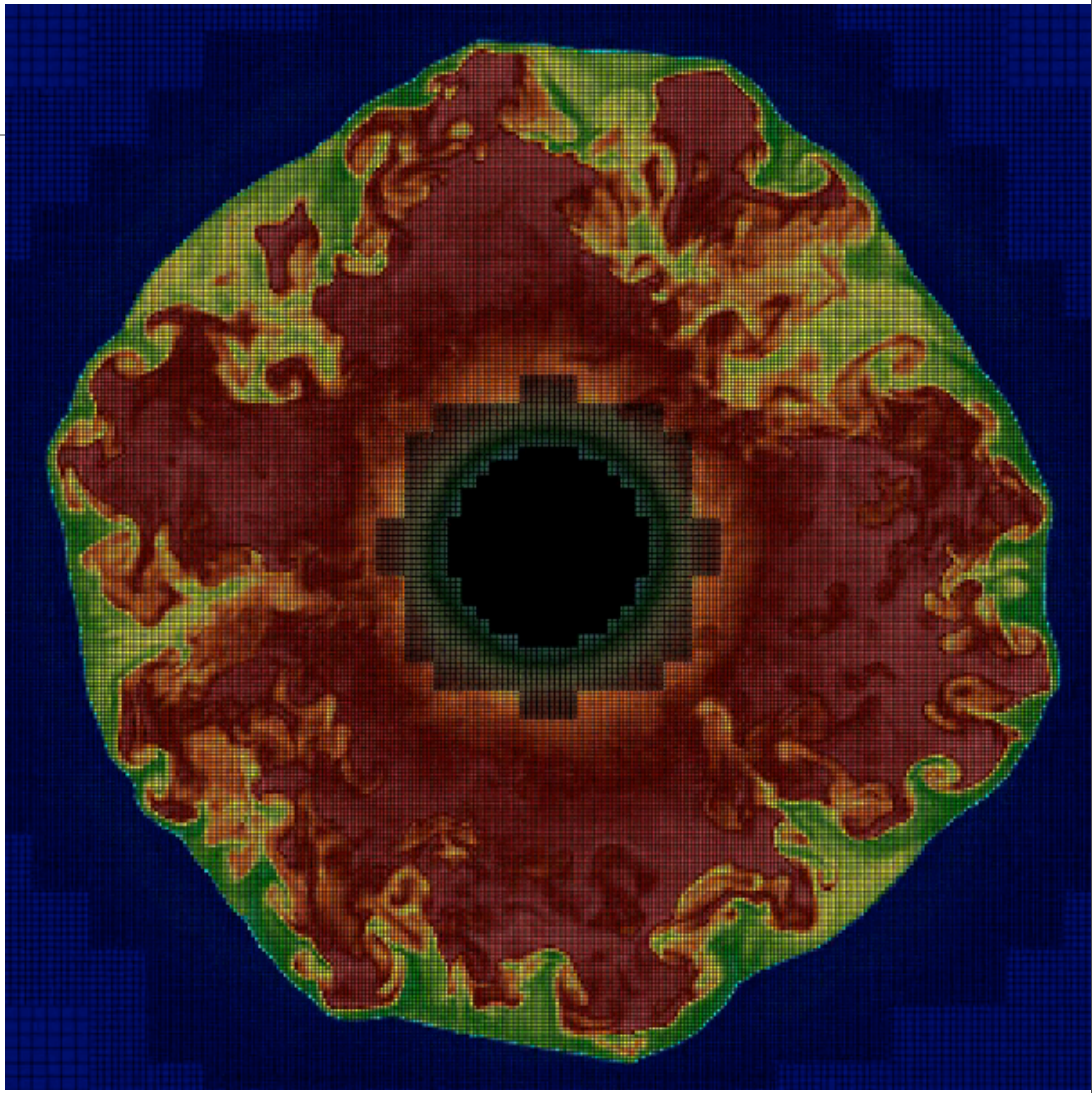
# Multi-D hydrodynamics is **a** key ingredient...

But of course we should worry about

- Neutrino transport
- Microphysics (EOS)
- General relativity
- Progenitors

# Numerical Setup

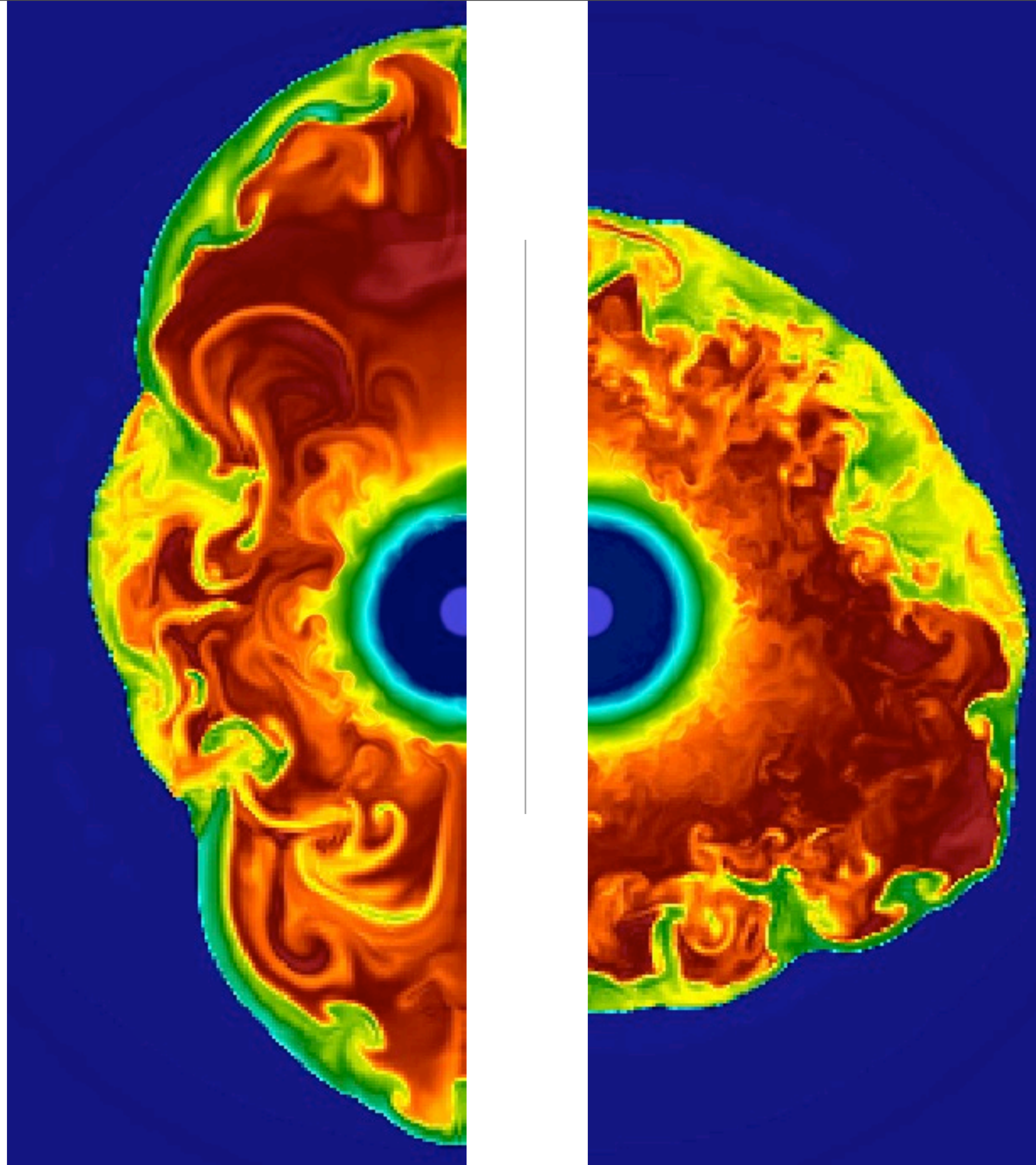
- CASTRO: AMR Godunov
- Monopole gravity
- $H = H_0 \frac{L_{\nu_e}}{r^2}(x_n + x_p)e^{-\tau}$
- $C = C_0 T^6 (x_n + x_p)e^{-\tau}$
- Shen et al. (1998) EOS
- $15\,M_\odot$ Woosley & Weaver ('95)
- Liebendörfer's $Y_e$ scheme



# Results

2D is not 3D.

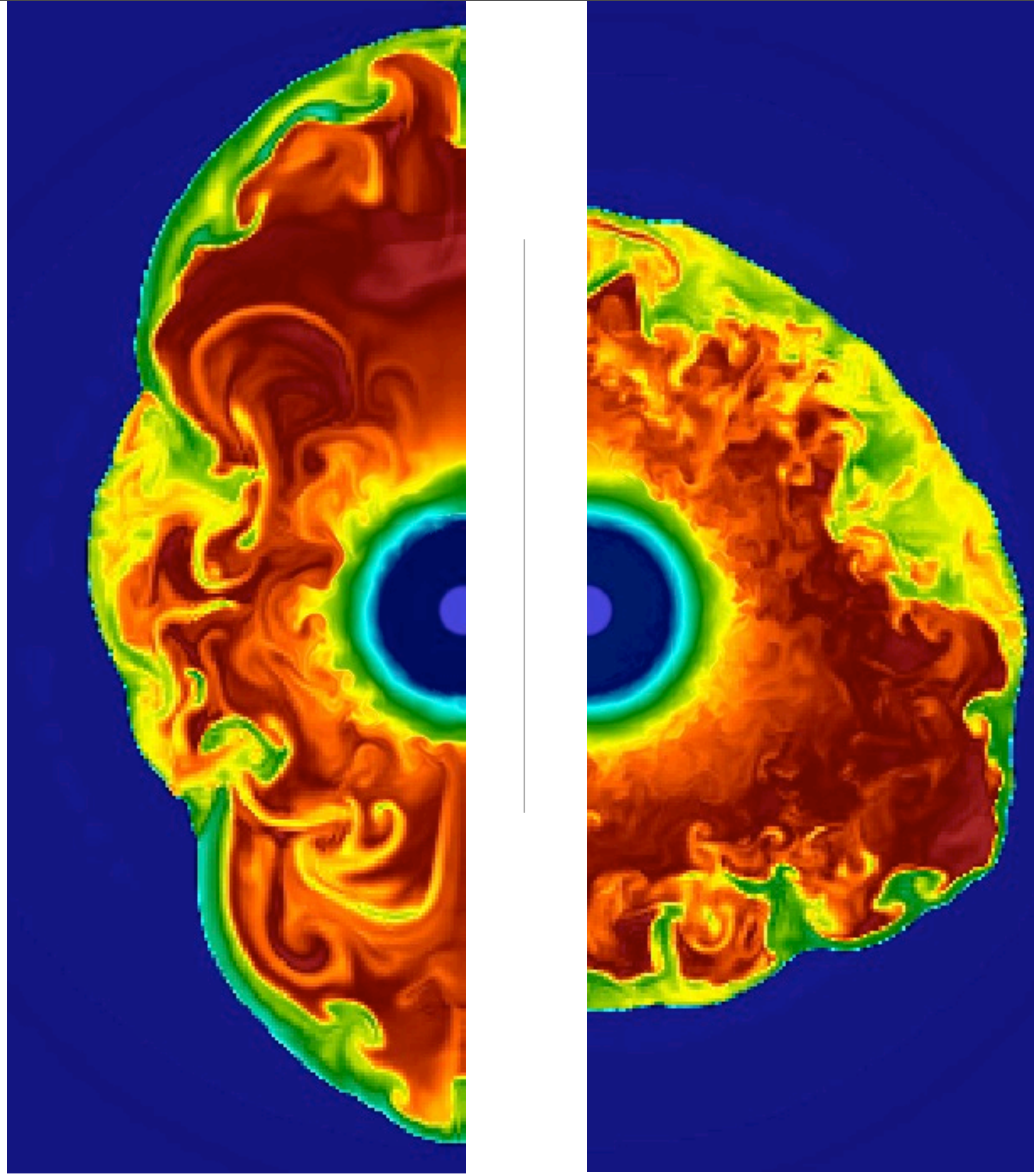
?D



?D

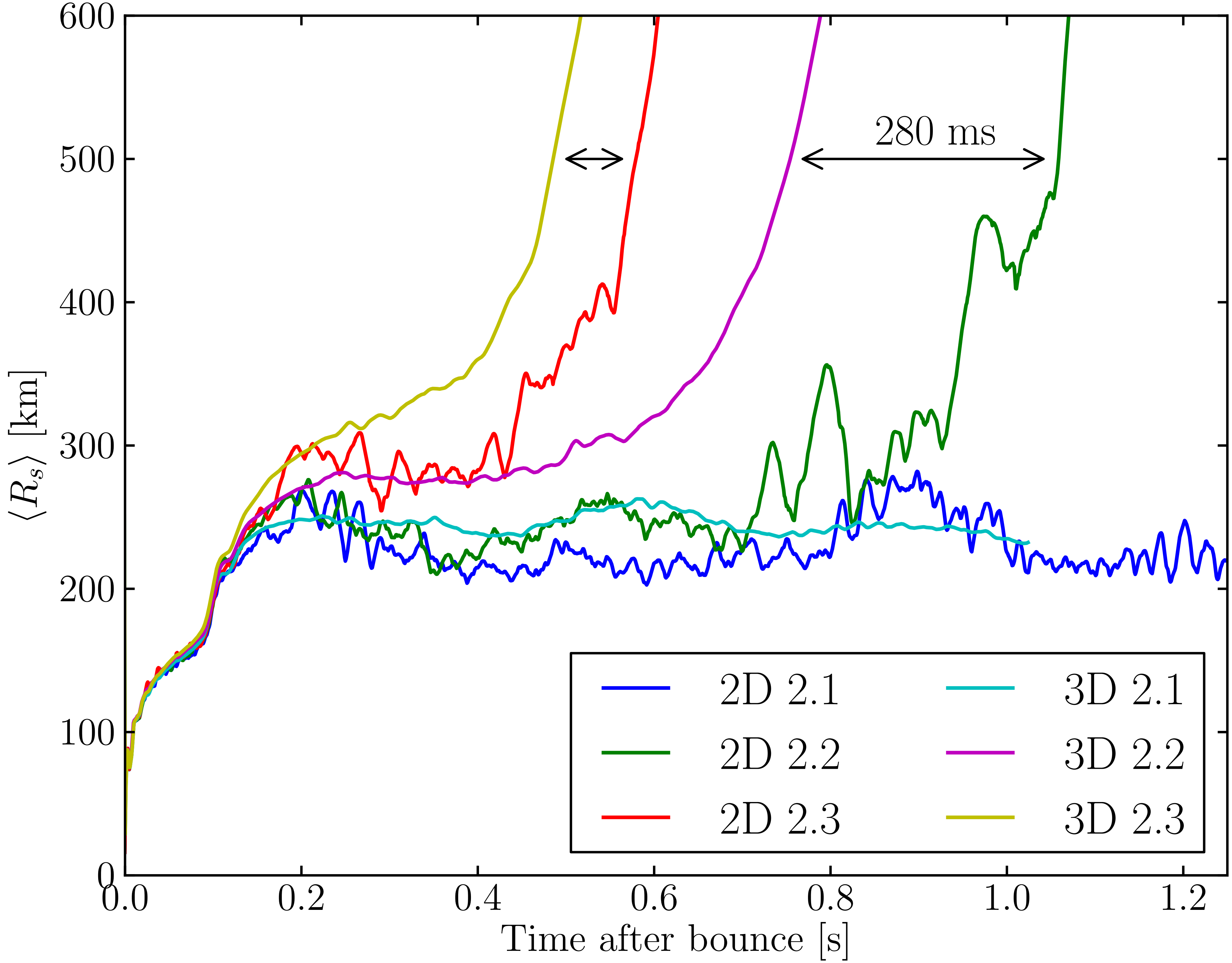
Pop quiz: How many dimensions am I?

2D



3D

Flows are different, even by eye.

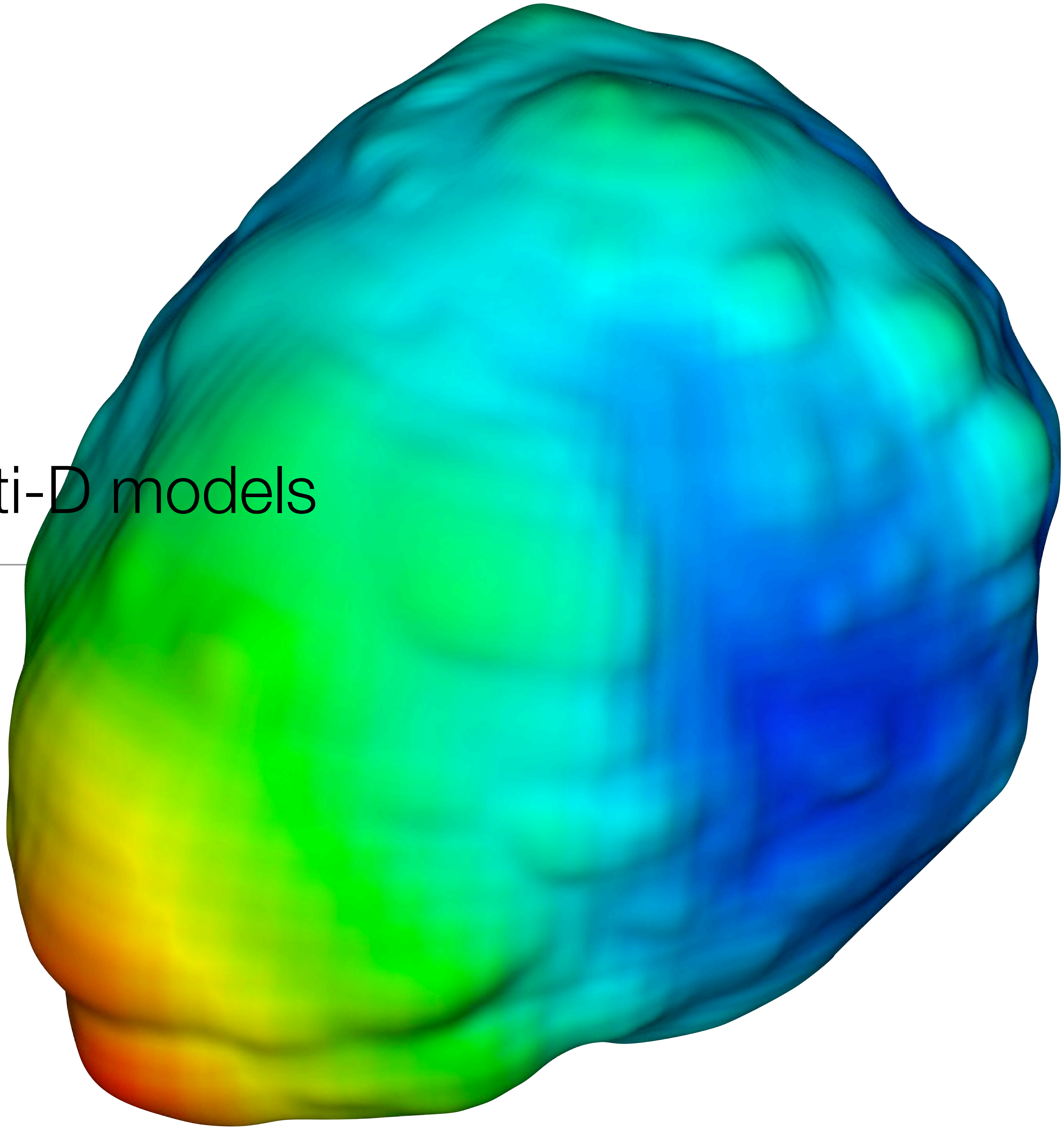


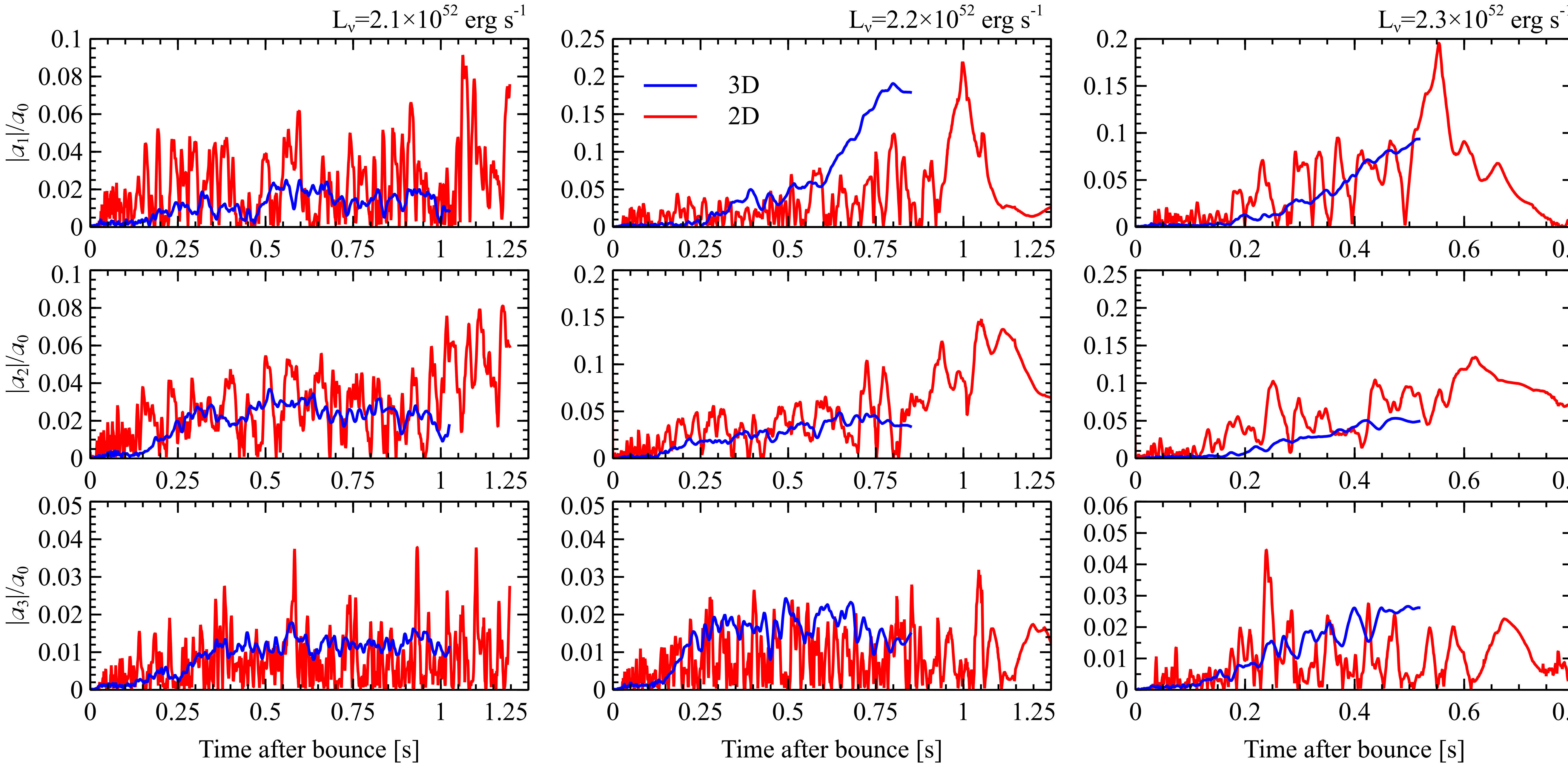

Does it matter?

Yes

# Structure of multi-D models

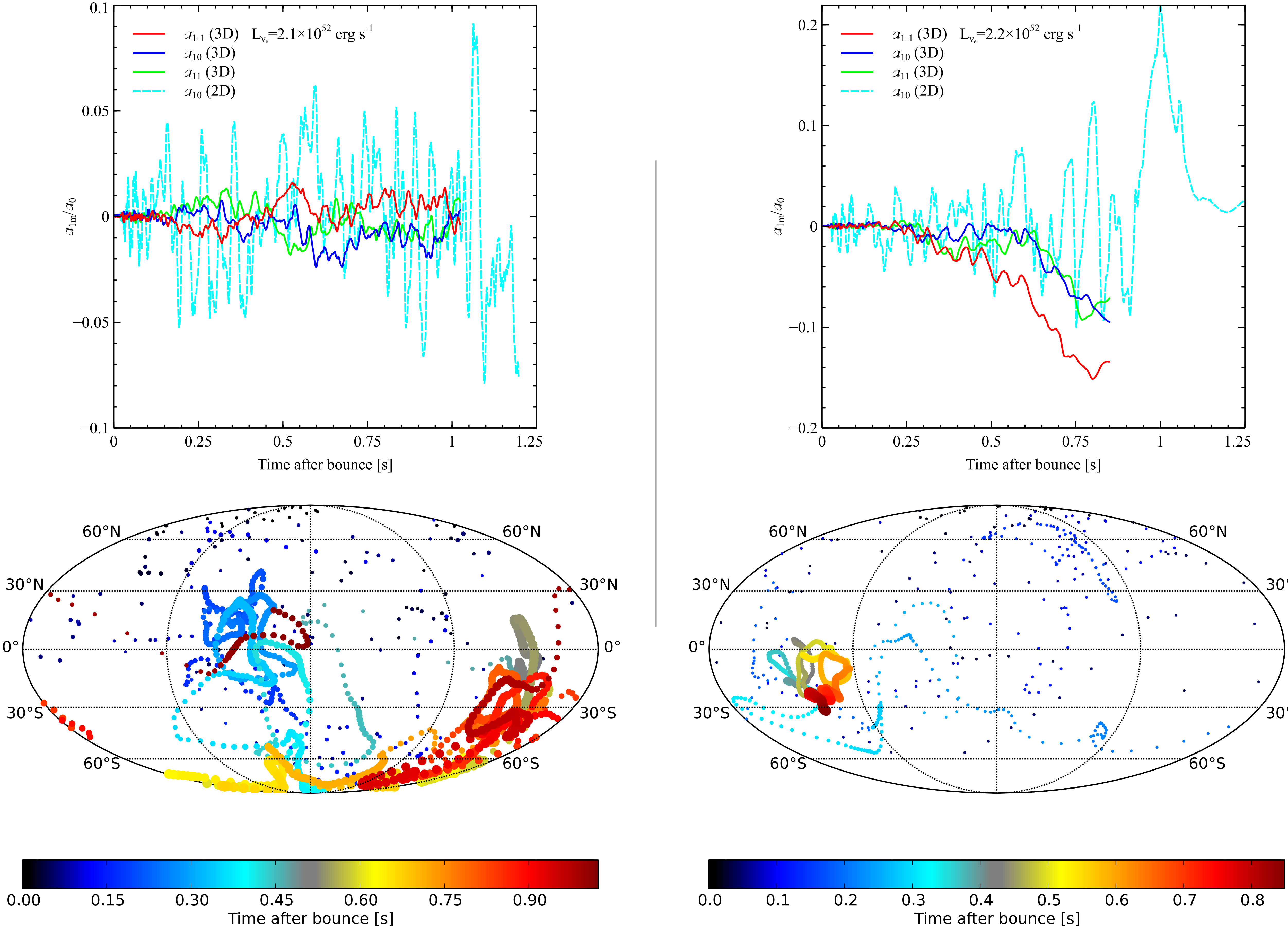
1. The shock





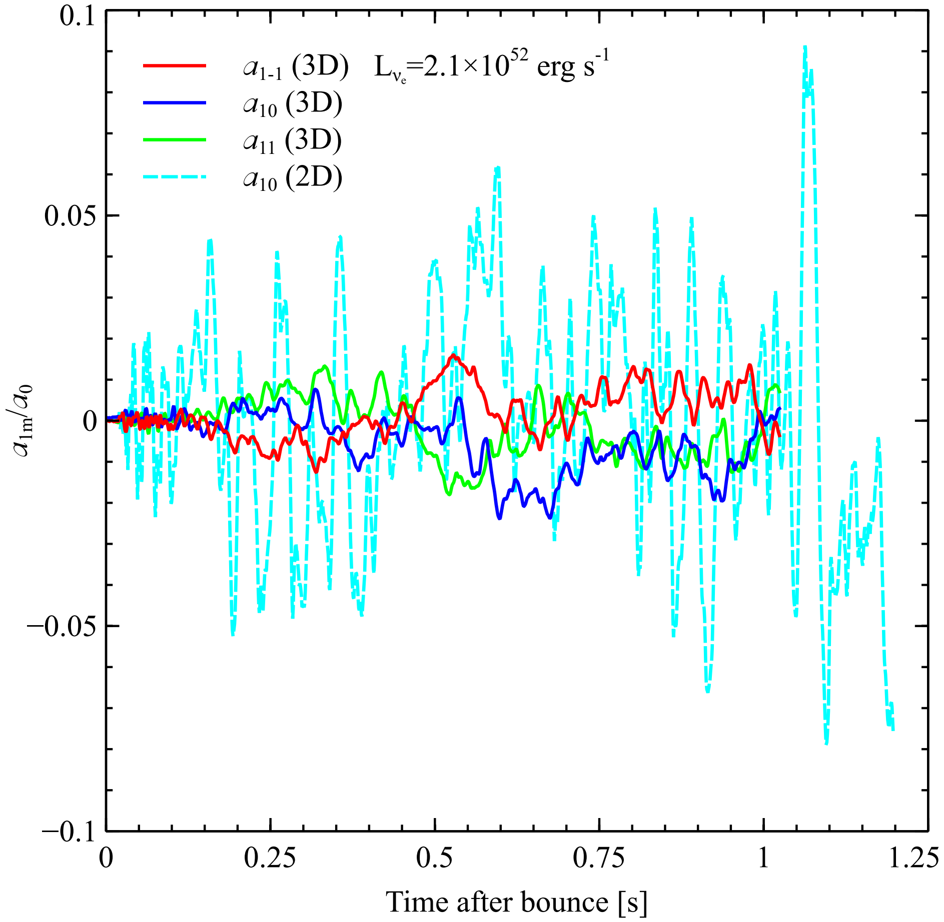

Burrows et al. 2012

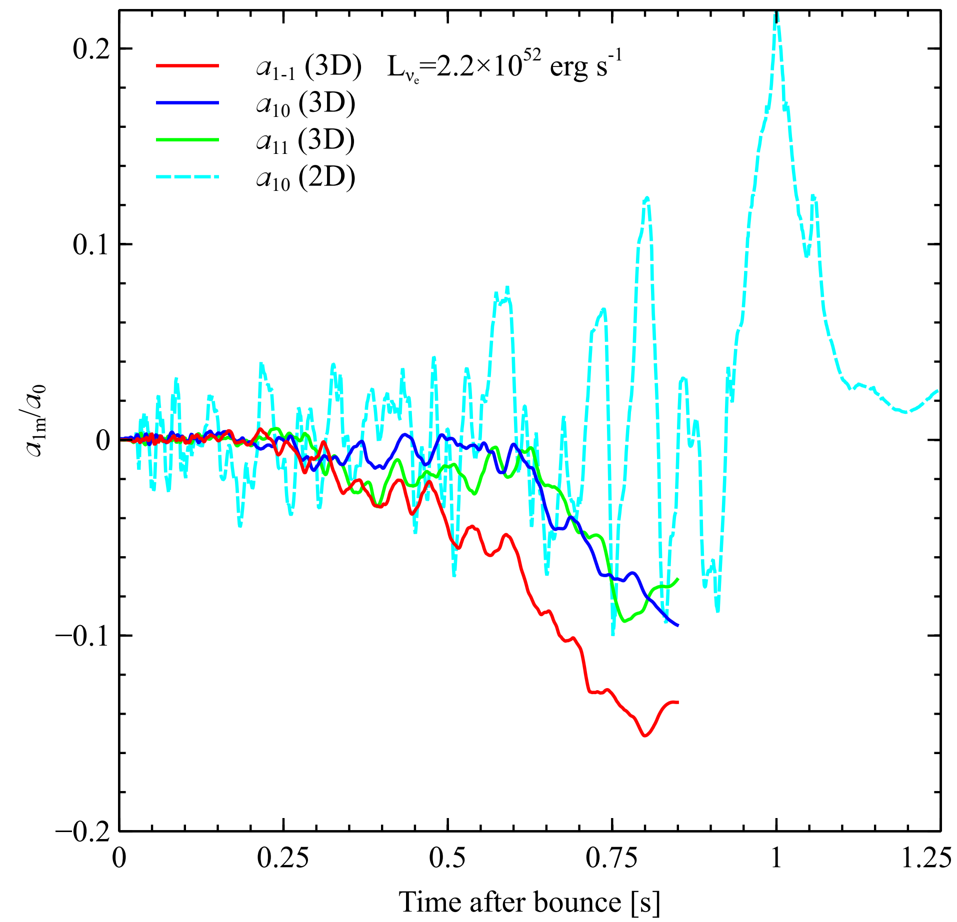
$$a_l^m = \frac{(-1)^{|m|}}{\sqrt{4\pi(2l+1)}} \oint R_s(\theta,\phi) Y_l^m(\theta,\phi) d\Omega$$

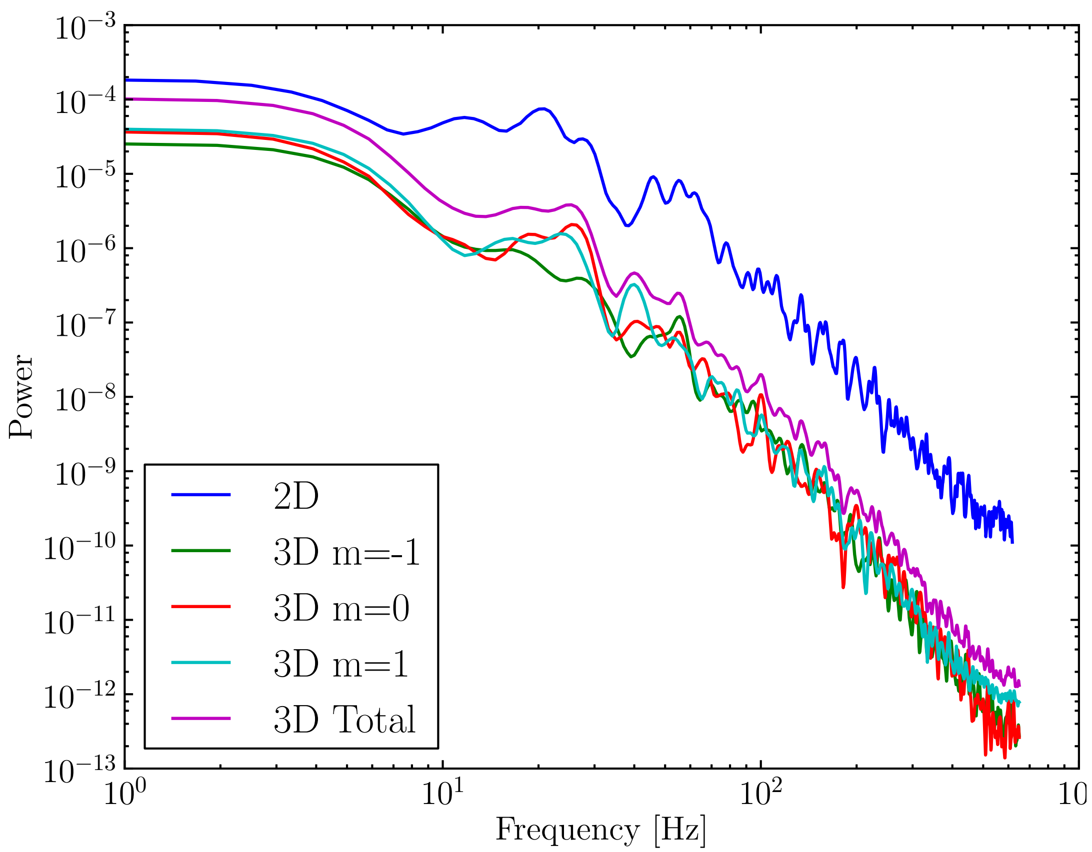


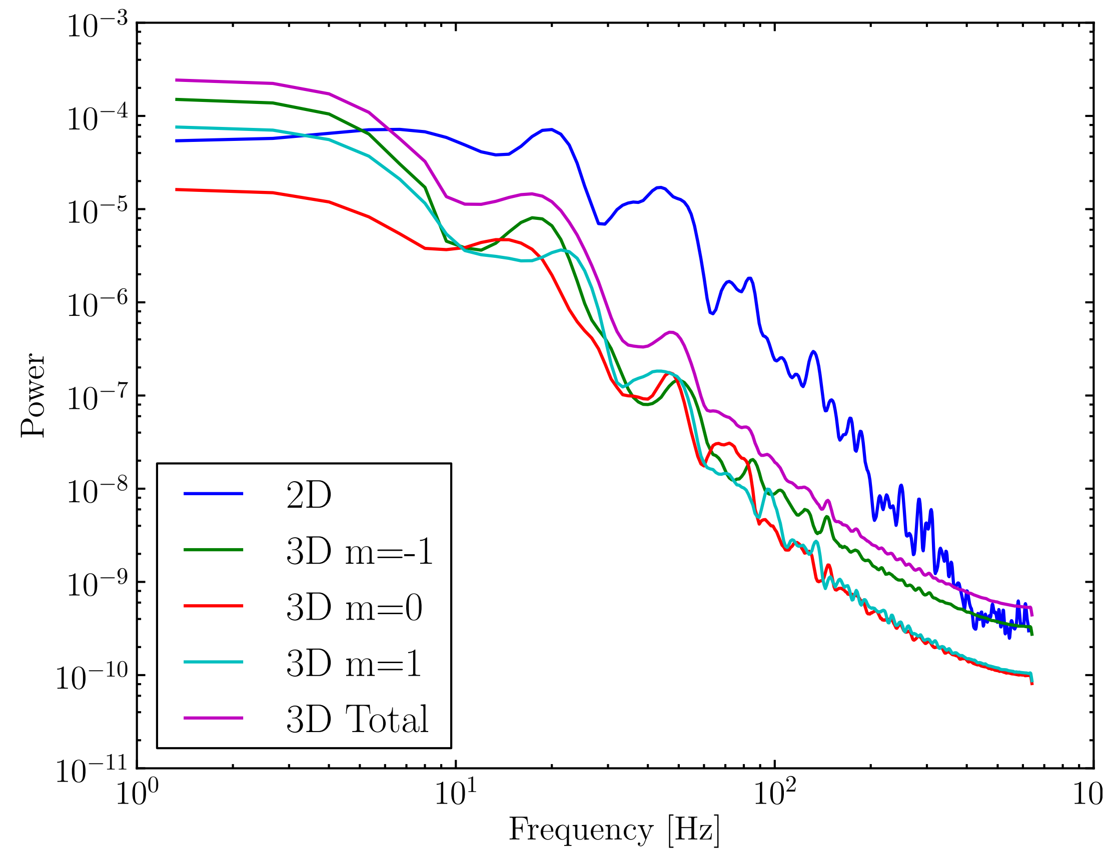

## Where's the "sloshing" in 3D?

Burrows et al. 2012

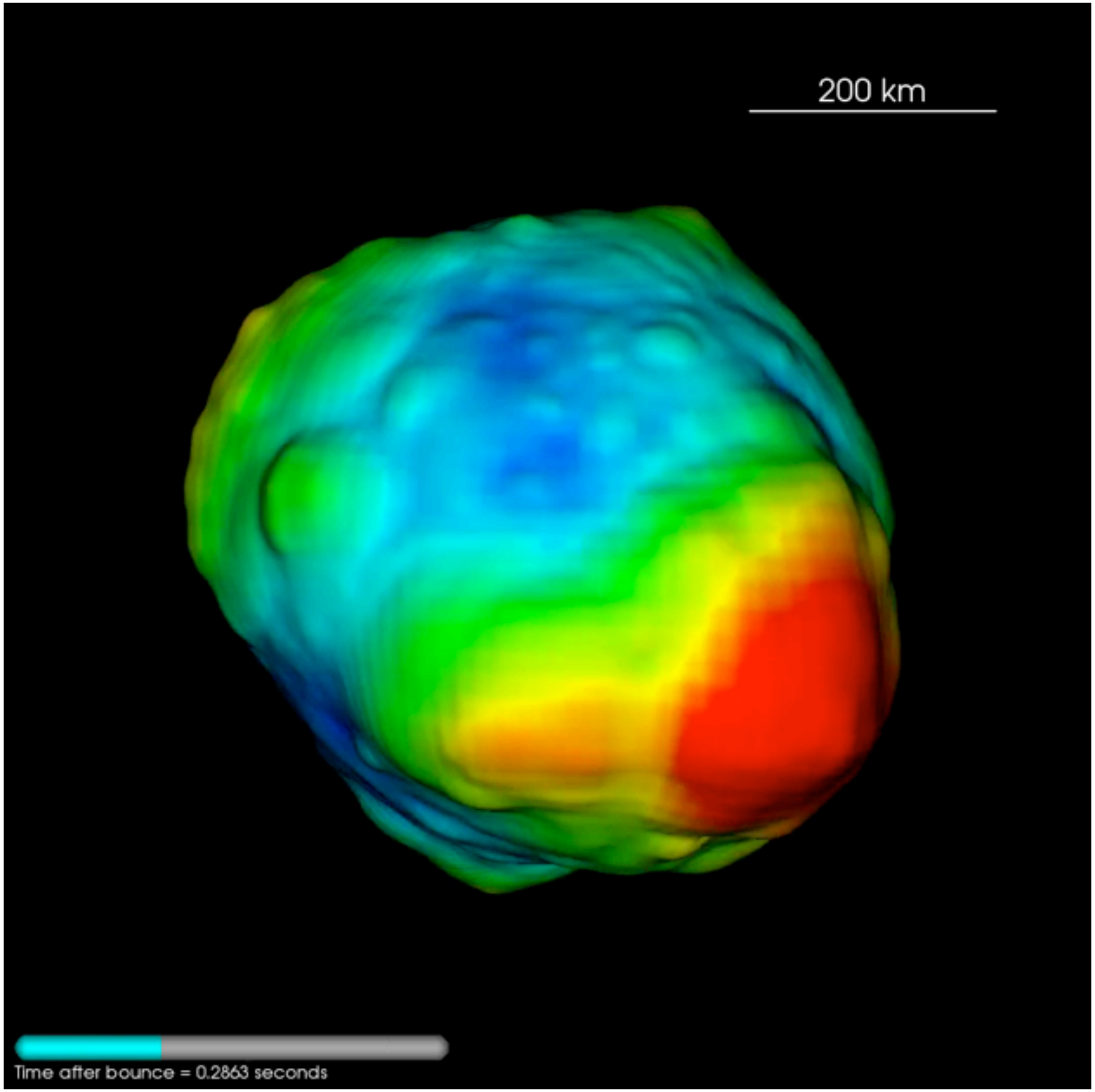


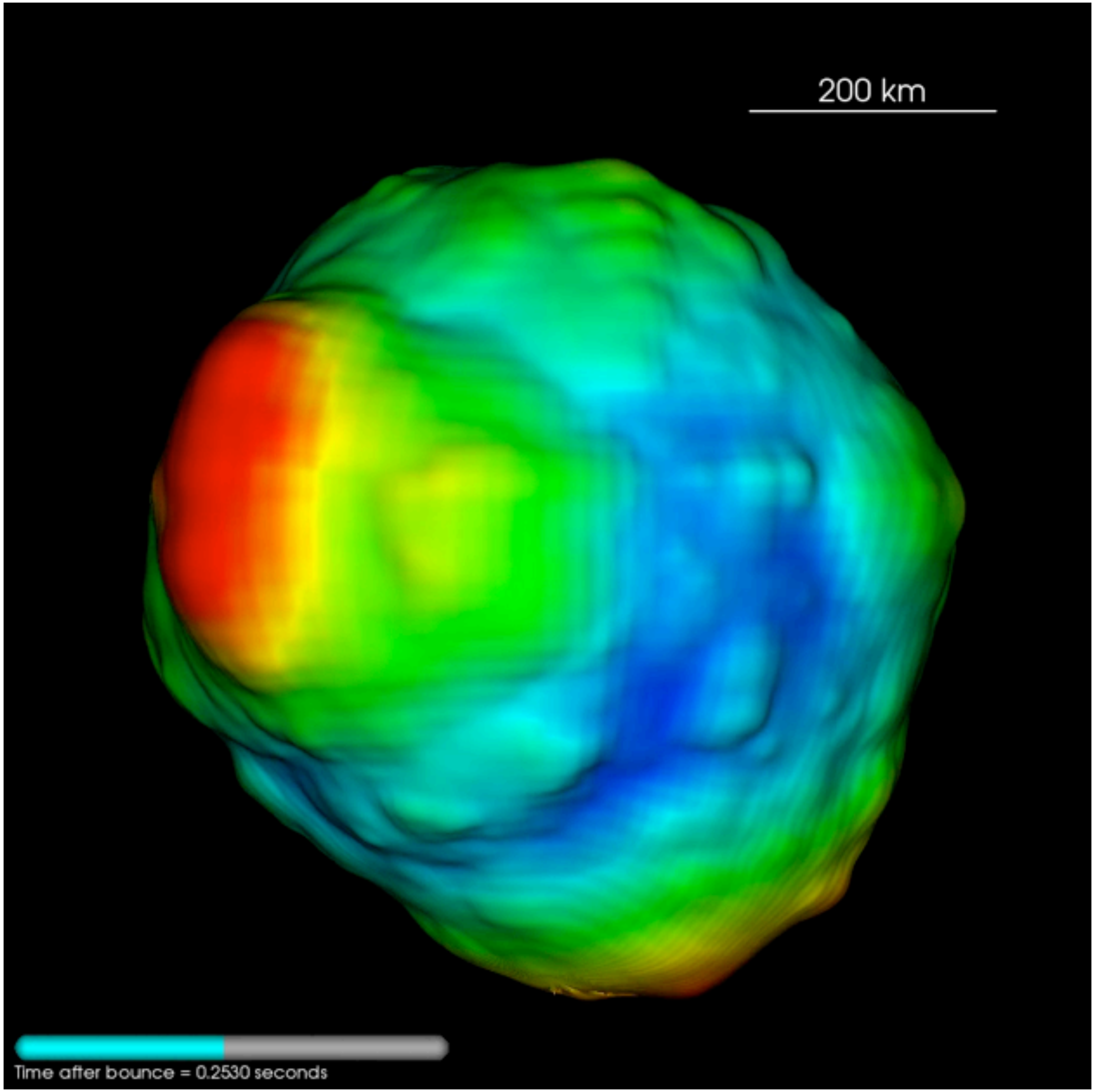




Where's the "sloshing" in 3D?



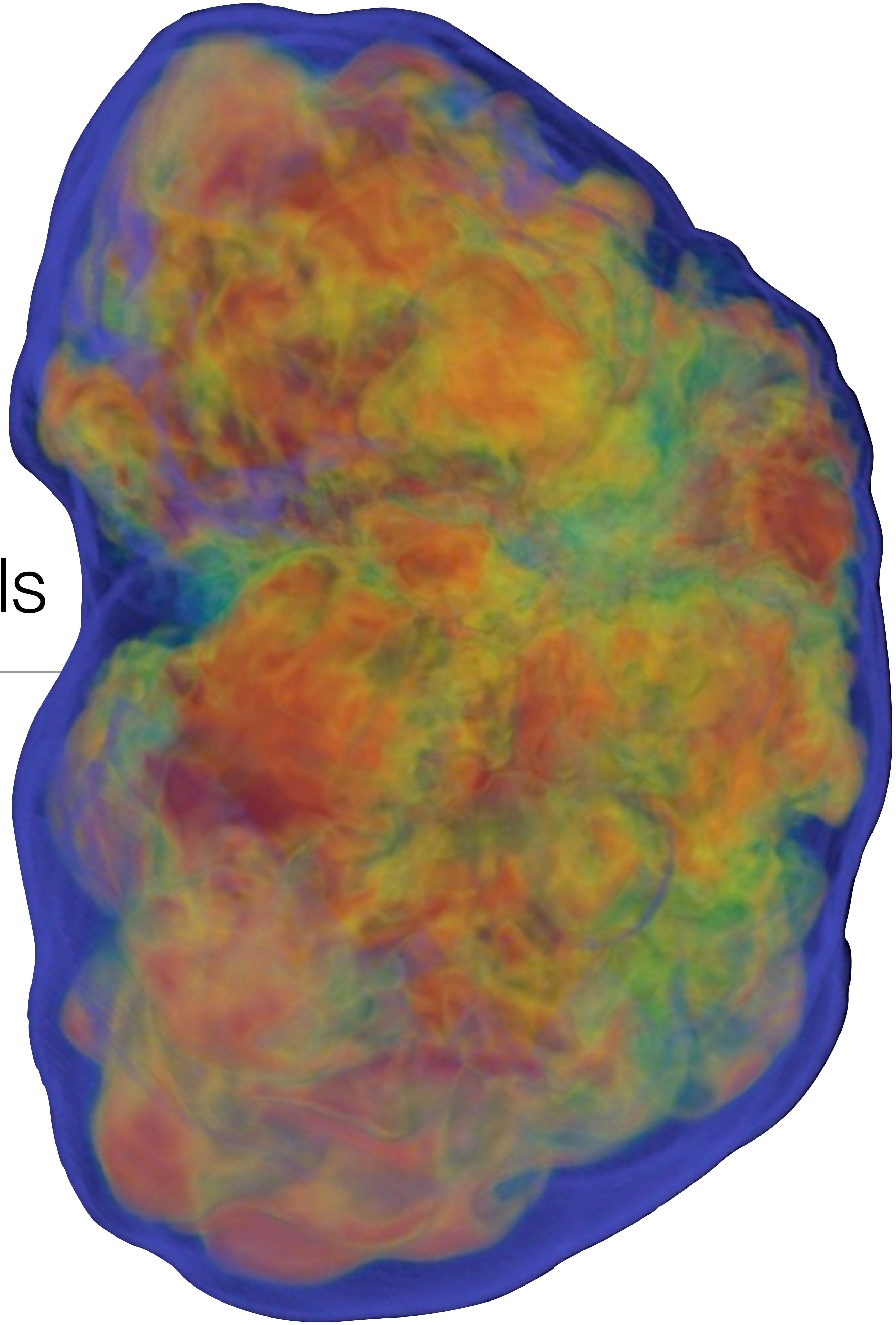

Evolution of the shock surface in 3D L=2.2 model

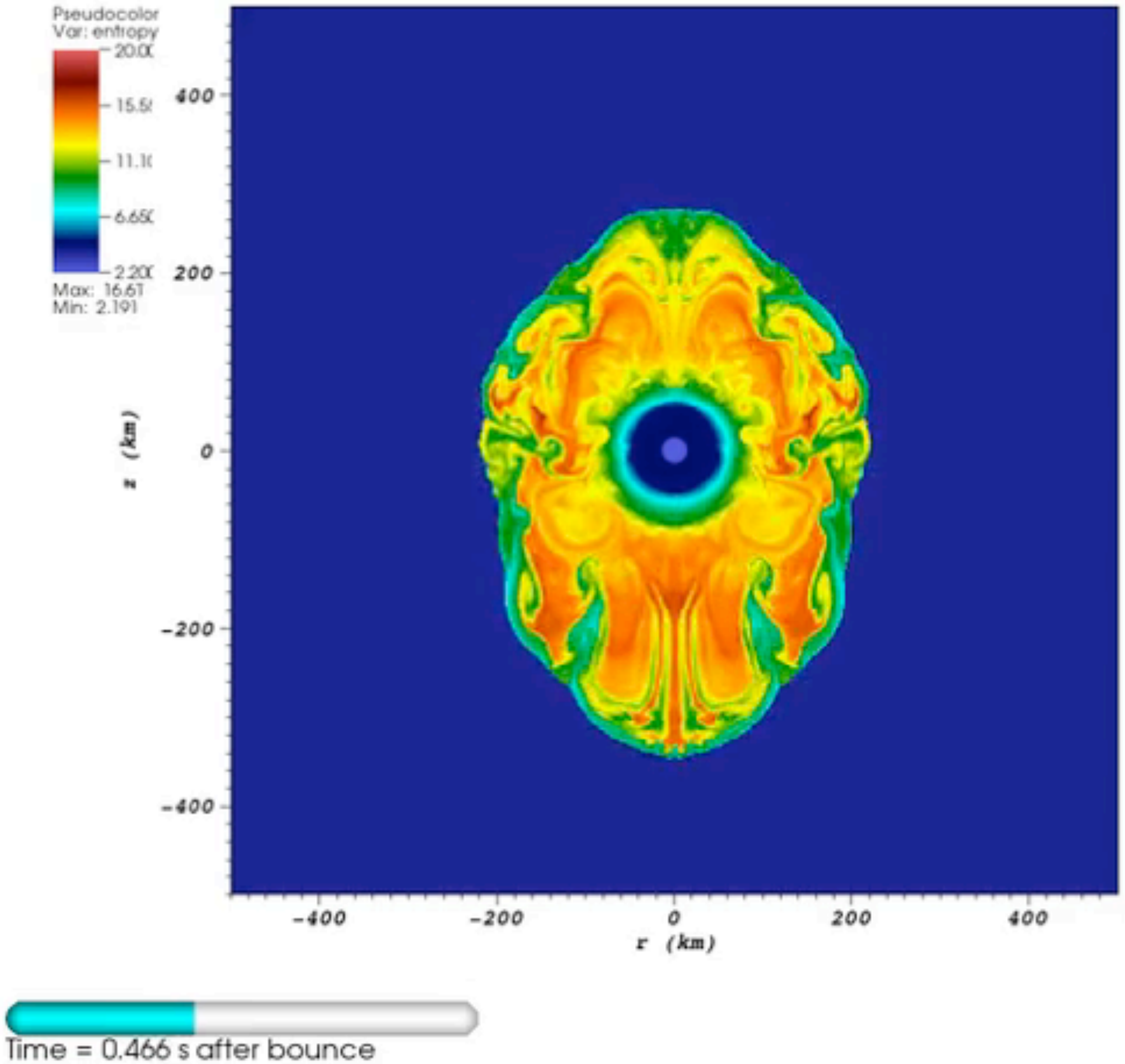


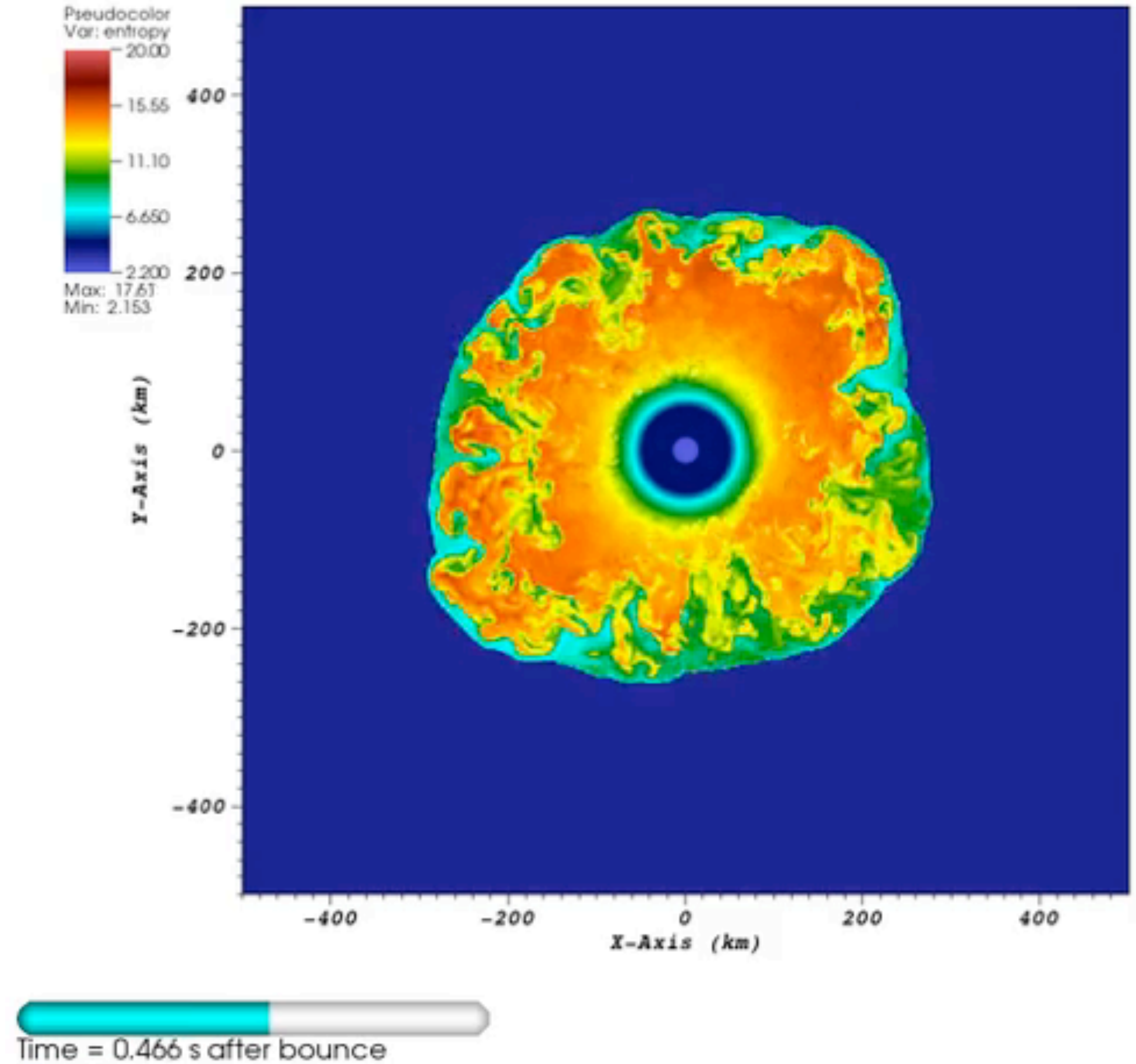

Evolution of the shock surface in 3D L=2.3 model

# Structure of multi-D models

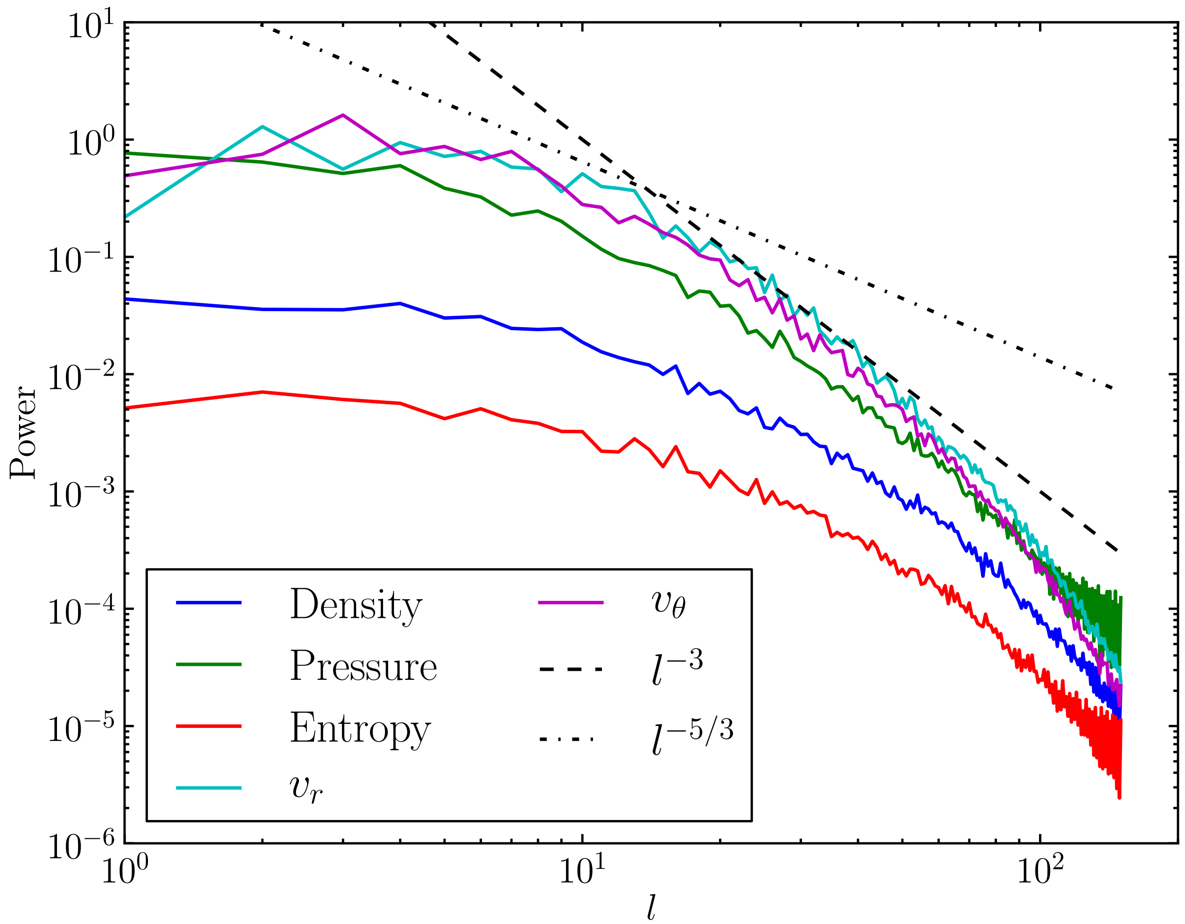
2. Turbulence

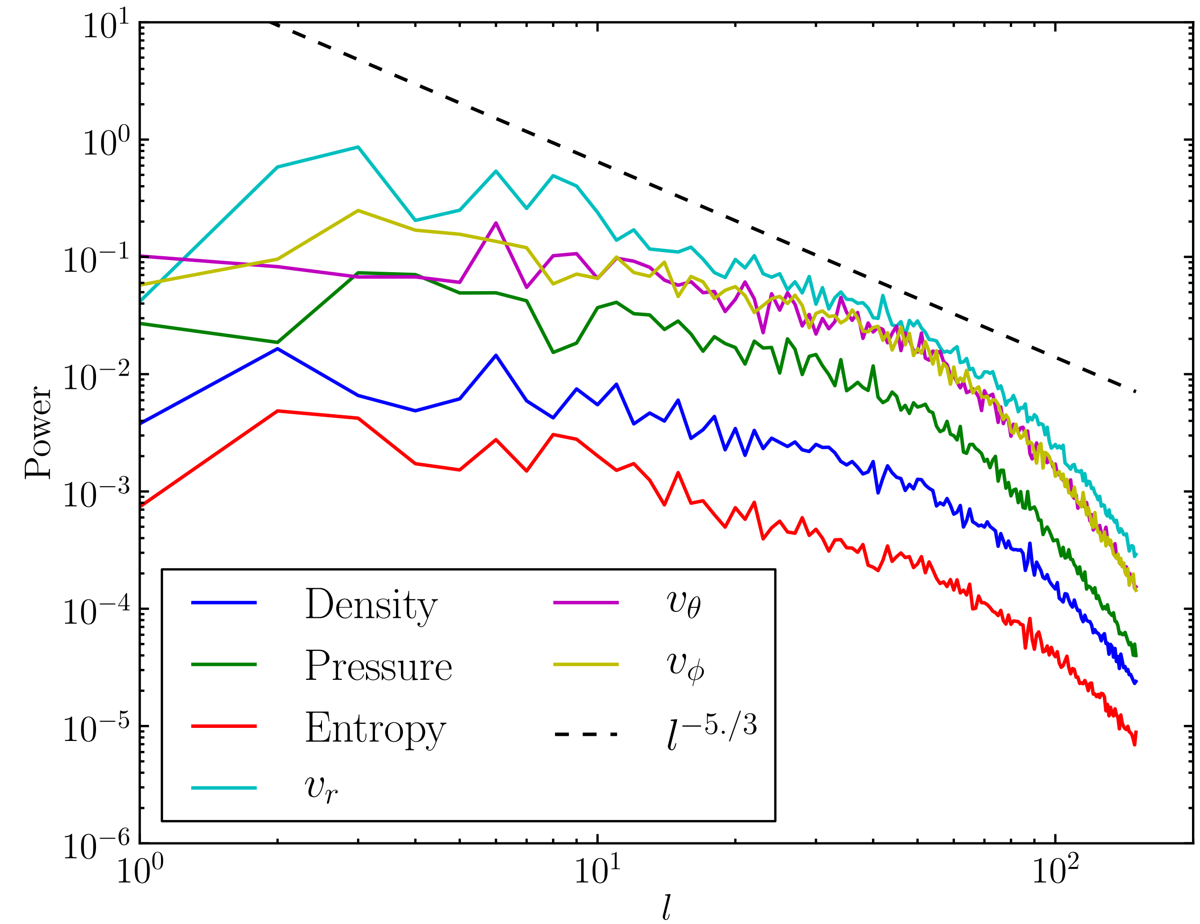




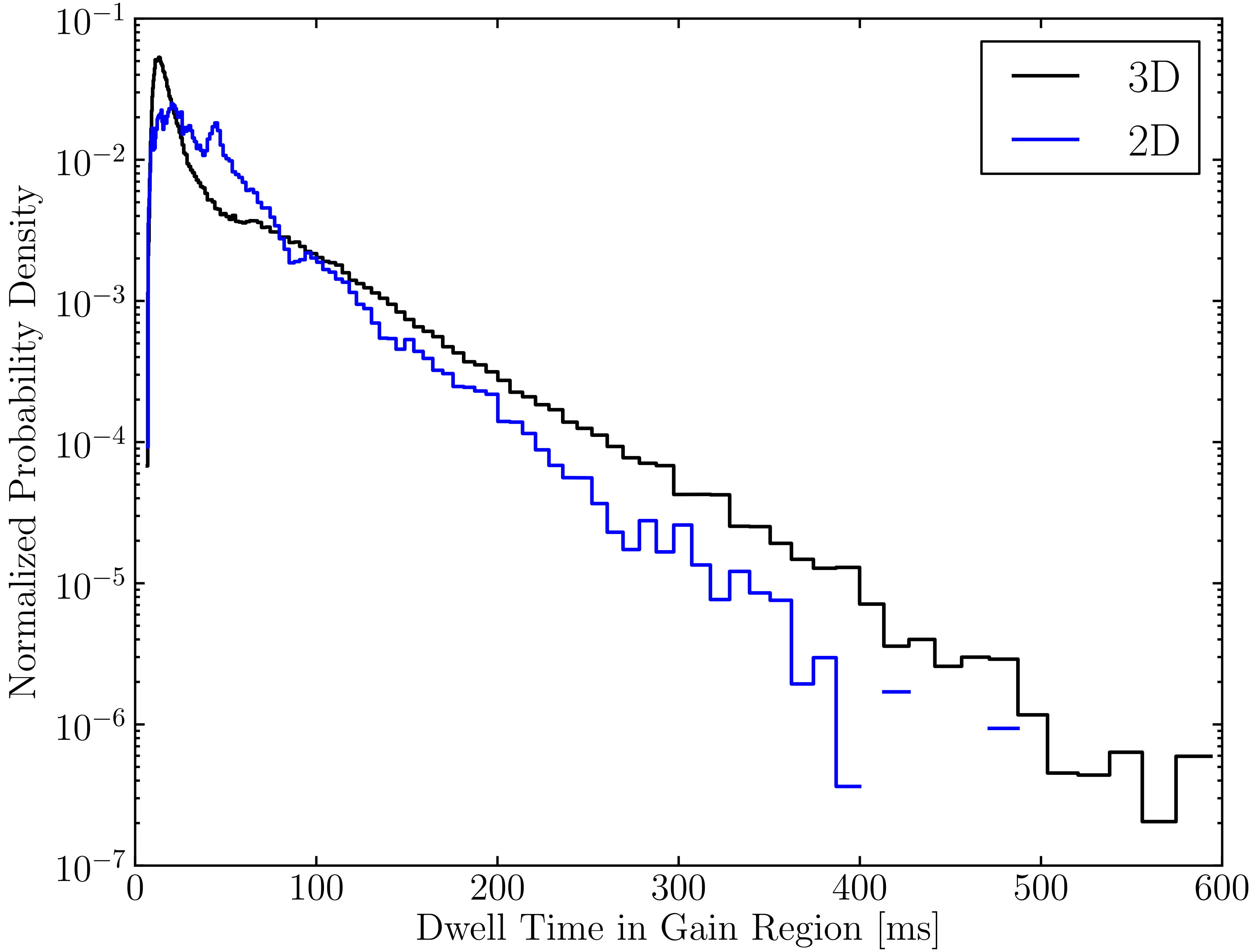

2D and 3D nonlinear turbulence are **different**.



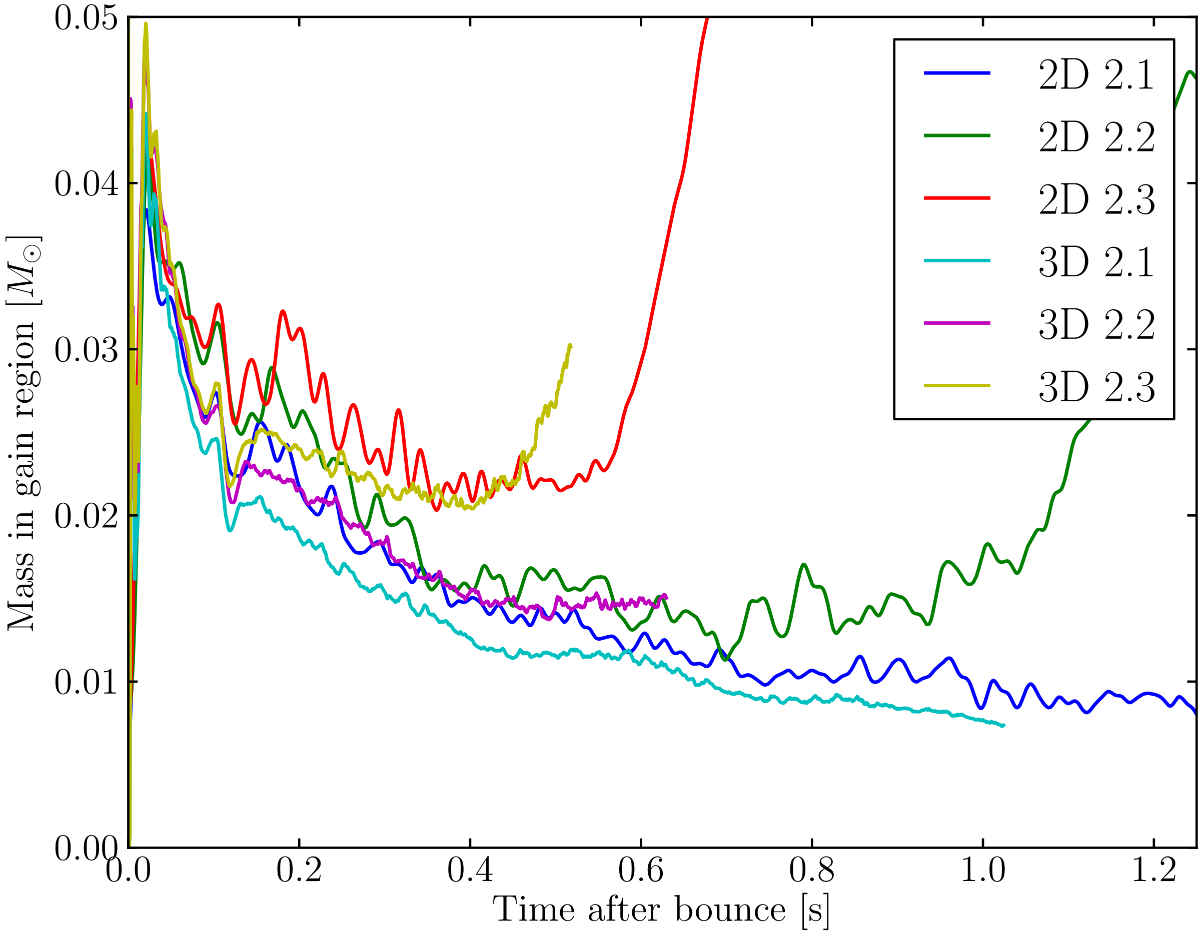



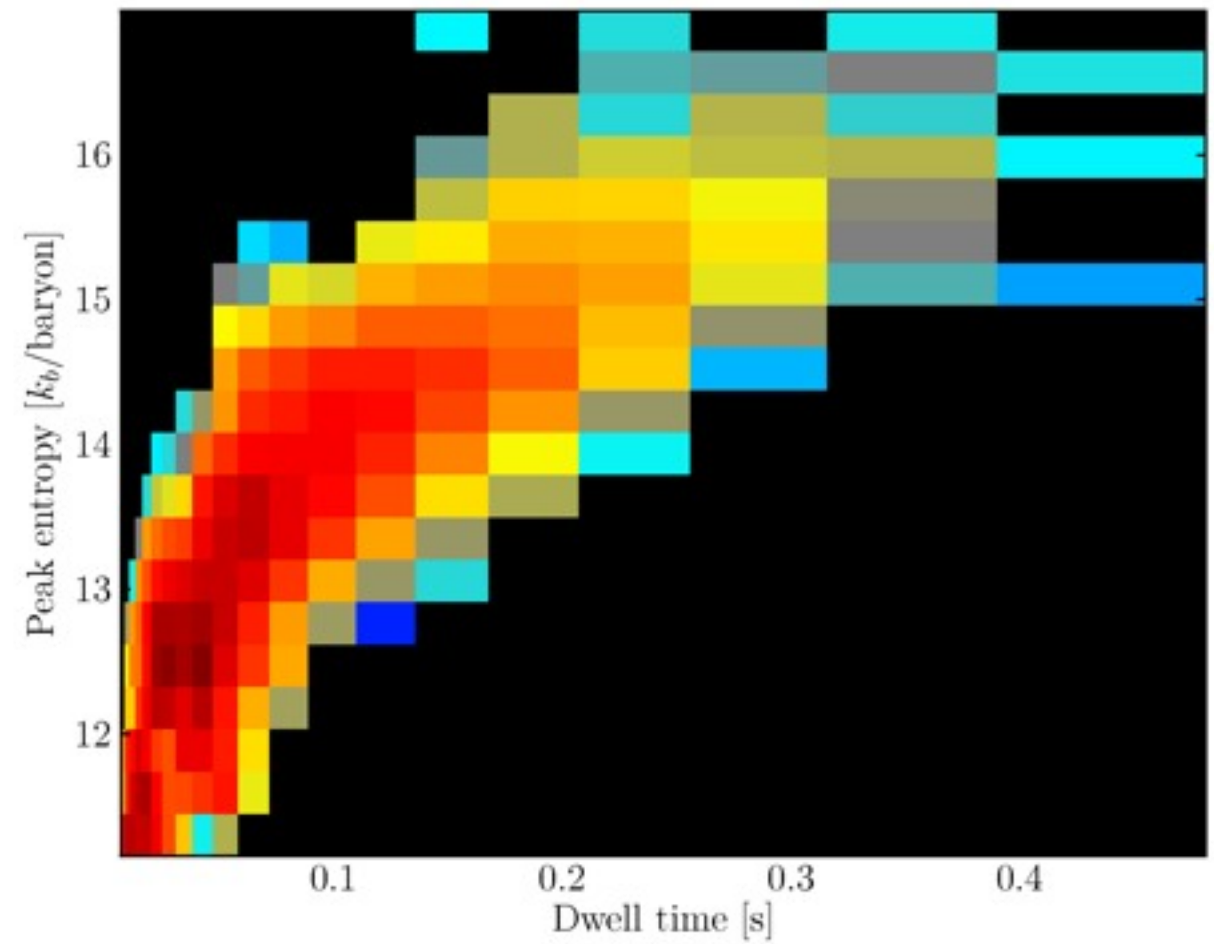

Power distributed differently. Inverse vs. forward energy cascades?

See Hanke et al. 2012 for similar plots.




2D has longer *mean* dwell time but 3D has long tail




Which is more important?

# Conclusions

- 2D & 3D shock structure and evolution are ***different***
- 2D & 3D power spectra of turbulence are ***different***
- 2D & 3D dwell time distributions are ***different***
- ***Yet explosions occur earlier in 3D. Why?***