FLASH sample results for KITP turbulence code comparison

Test problem 1, pure hydro and MHD

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and

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ZAH Heidelberg, April 2008

initial conditions and project description at
http://kitpstarformation07.wikispaces.com/Star+Formation+Test+Problems

FLASH3 code info at
http://flash.uchicago.edu/website/codesupport

FLASH results – pure hydro (HD)

initial conditions: developed snapshot from a solenoidally driven isothermal turbulence simulation with periodic boundary conditions and rms Mach number ~9 without magnetic fields

4 simulations:

256^3 grid points with gamma=1.001 to approximate an isothermal eos
256^3 grid points with with a polytropic eos and Gamma=1.0 (proper isothermal)
512^3 grid points with with a polytropic eos and Gamma=1.0 (proper isothermal)
1024^3 grid points with with a polytropic eos and Gamma=1.0 (proper isothermal)

hydro solver: PPM (Colella & Woodward 1984)

analysis in terms of projections, slices, PDFs, spectra, structure functions, time evolution plots

FLASH results – magnetic runs (MHD)

initial conditions: developed snapshot from a solenoidally driven isothermal turbulence simulation with periodic boundary conditions and rms Mach number ~9 with magnetic fields tuned to minimize div B

3 simulations:

- 128^3 grid points with with a polytropic eos and Gamma=1.0 (proper isothermal)
- 256^3 grid points with with a polytropic eos and Gamma=1.0 (proper isothermal)
- 512^3 grid points with with a polytropic eos and Gamma=1.0 (proper isothermal)

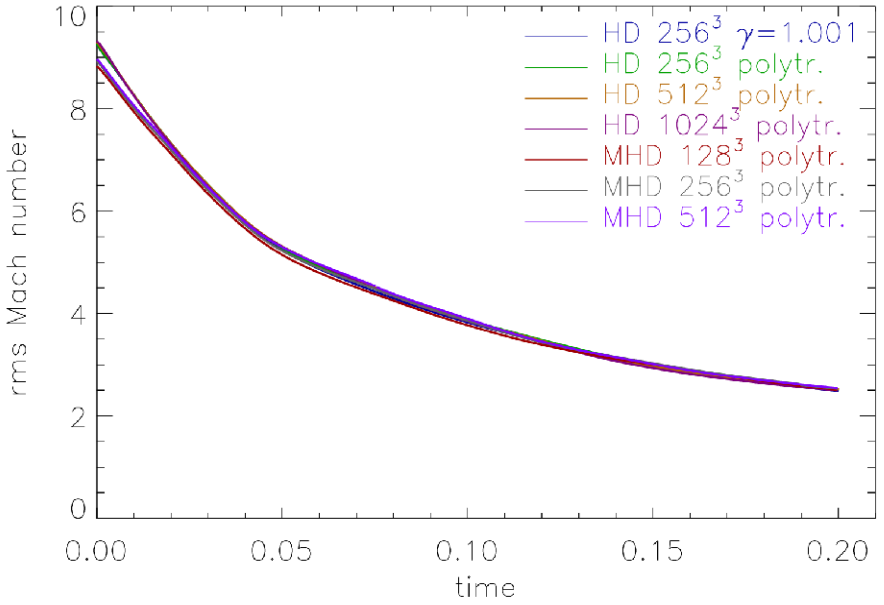
unsplit staggered mesh scheme for MHD implemented by Dongwook Lee (http://flash.uchicago.edu/website/codesupport)

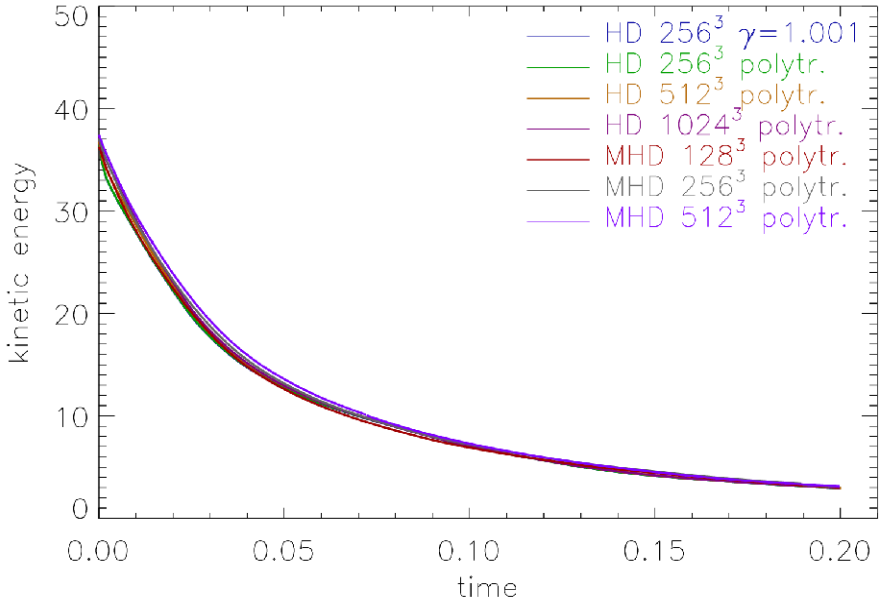
HLLD Riemann solver (Miyoshi & Kusano 2005)

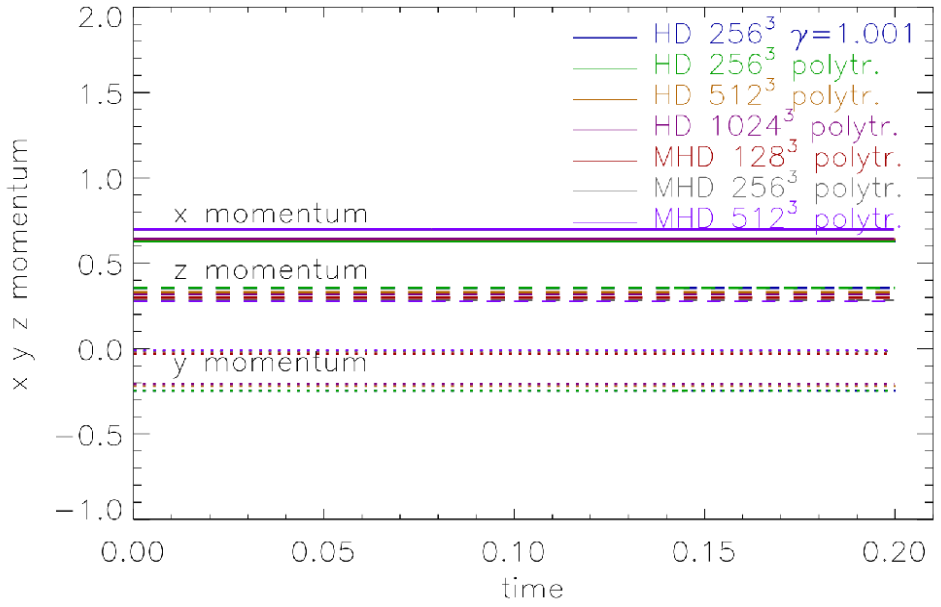
hybrid slope limiter (Balsara 2004)

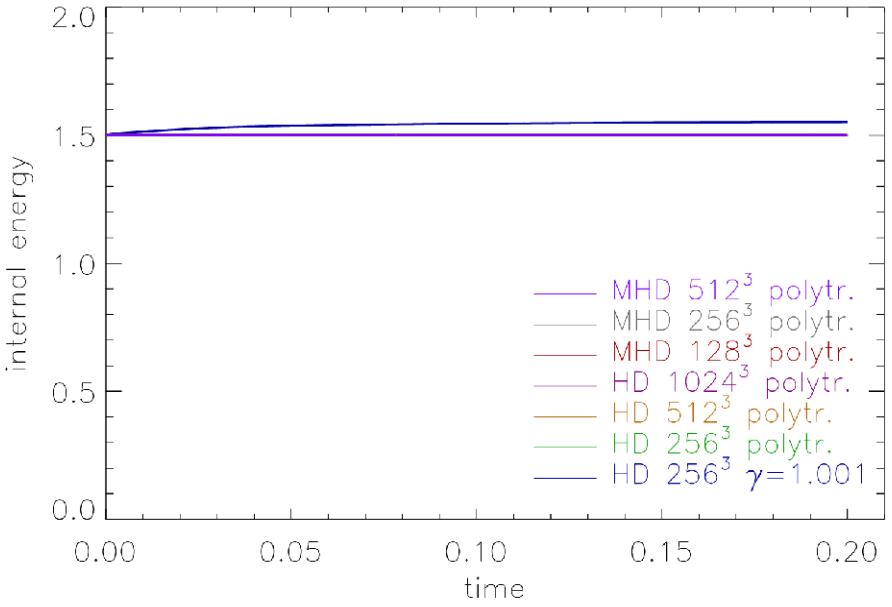
analysis in terms of projections, slices, PDFs, spectra, structure functions, time evolution plots

FLASH results – resolution and model study, time evolution

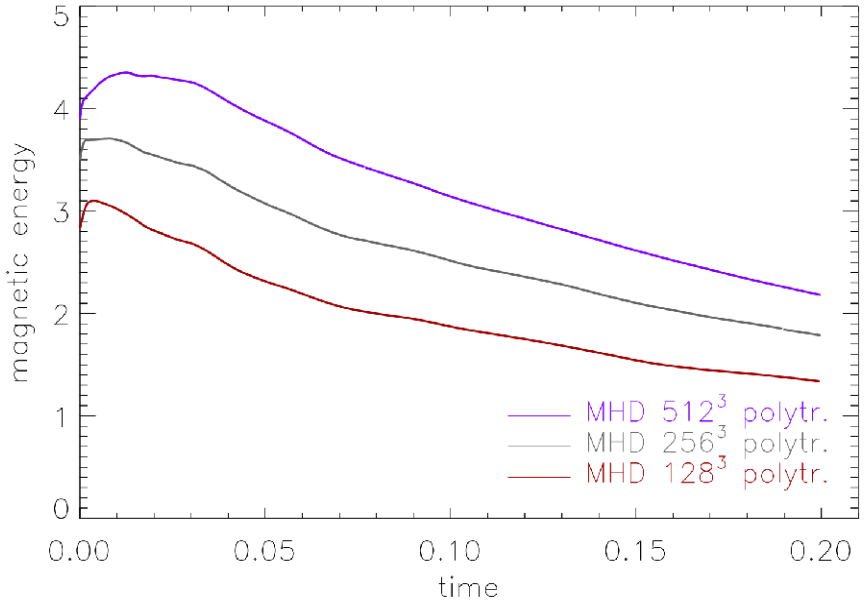


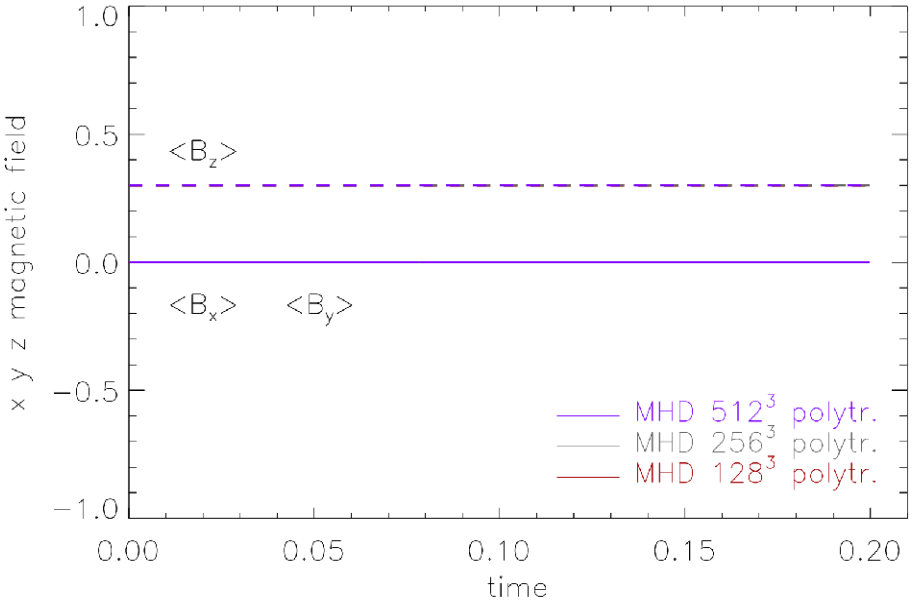


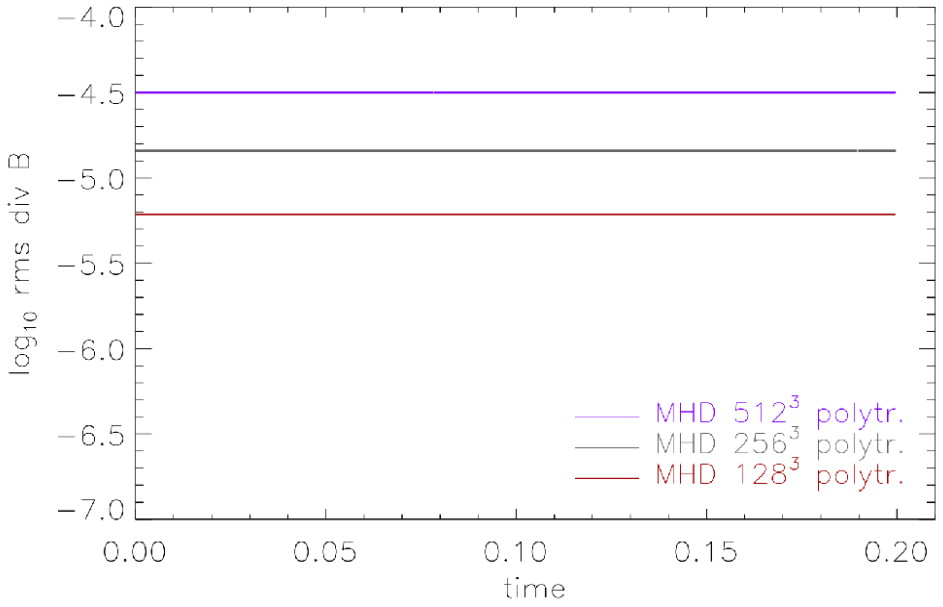


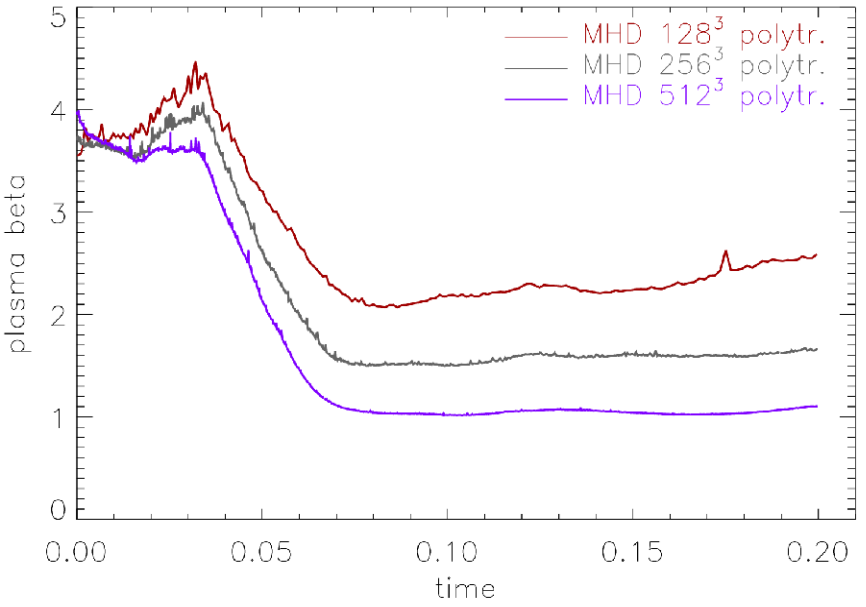


FLASH results – resolution and model study, time evolution



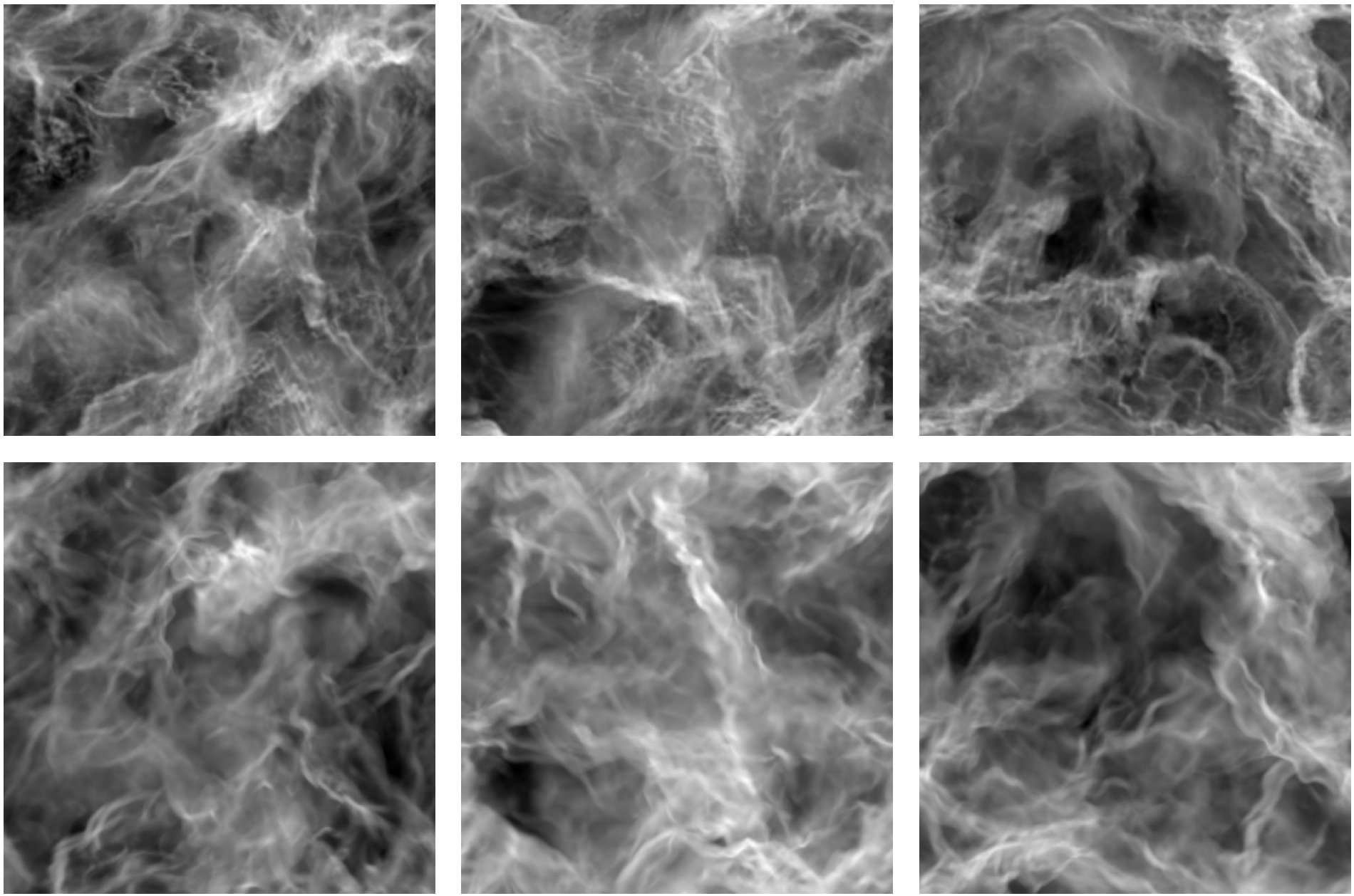




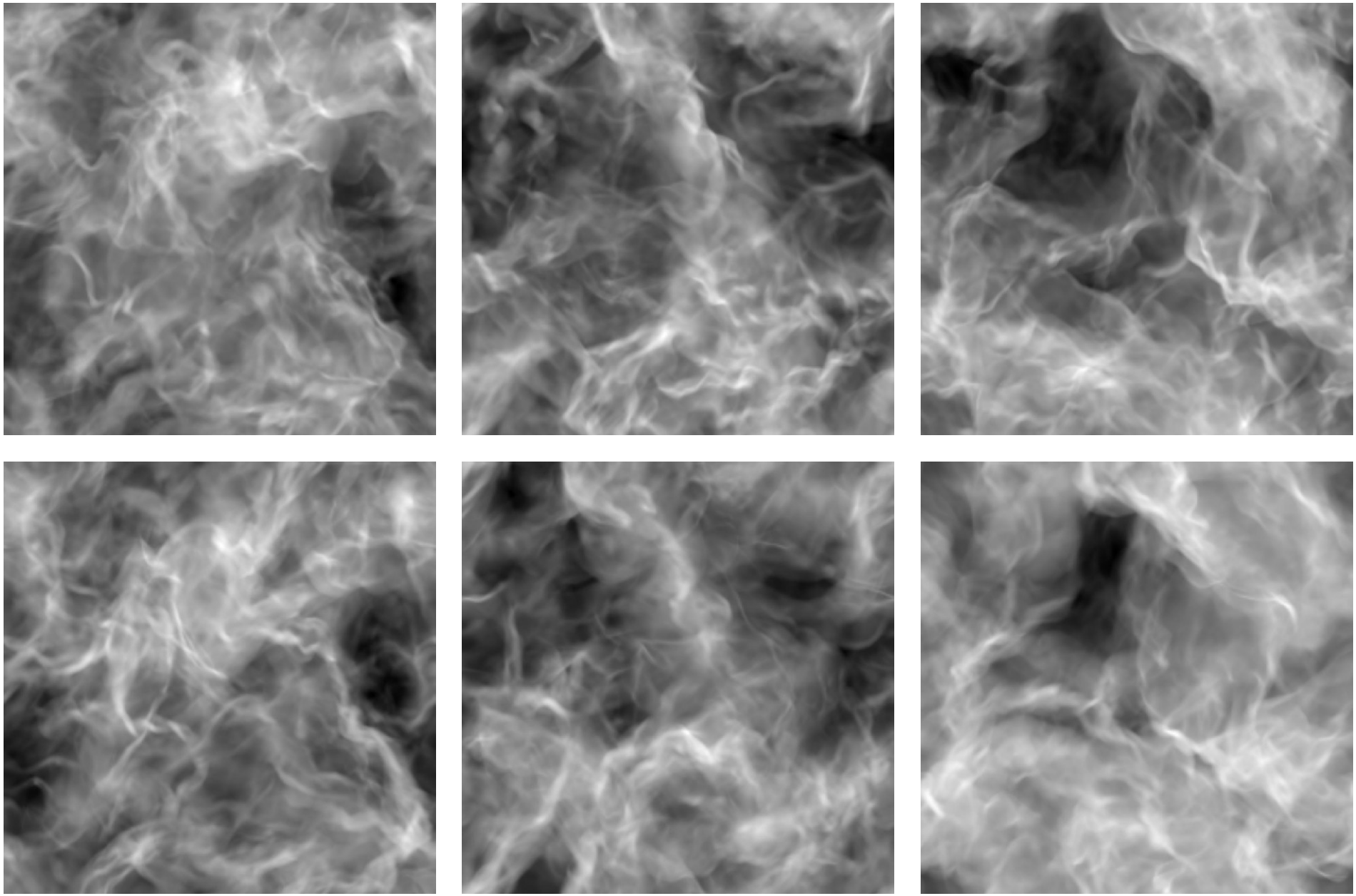


HD 256^3
with gamma=1.001
to approximate isothermality

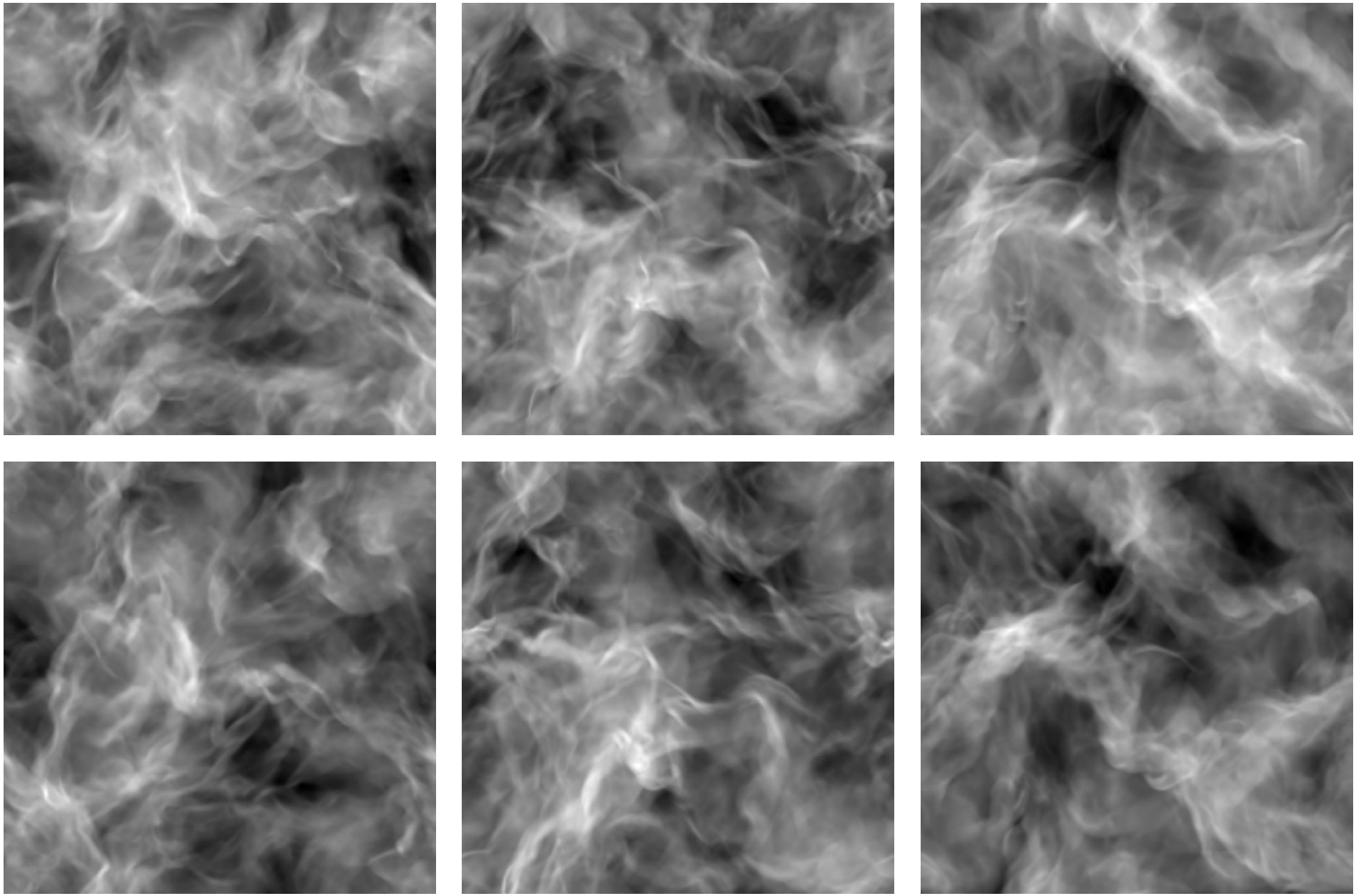
FLASH results – 256^3 gamma=1.001 column density



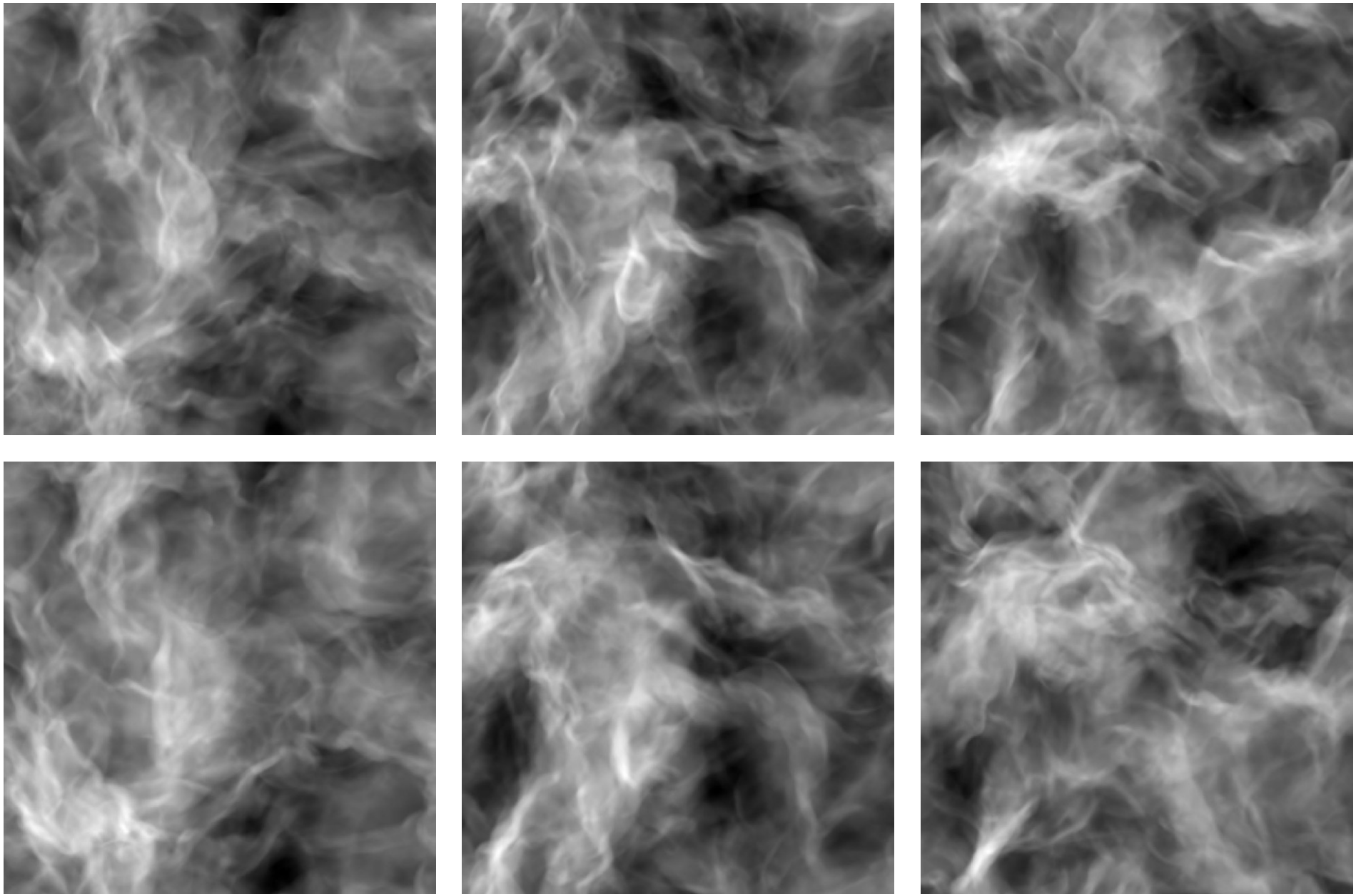
FLASH results – 256^3 gamma=1.001 column density



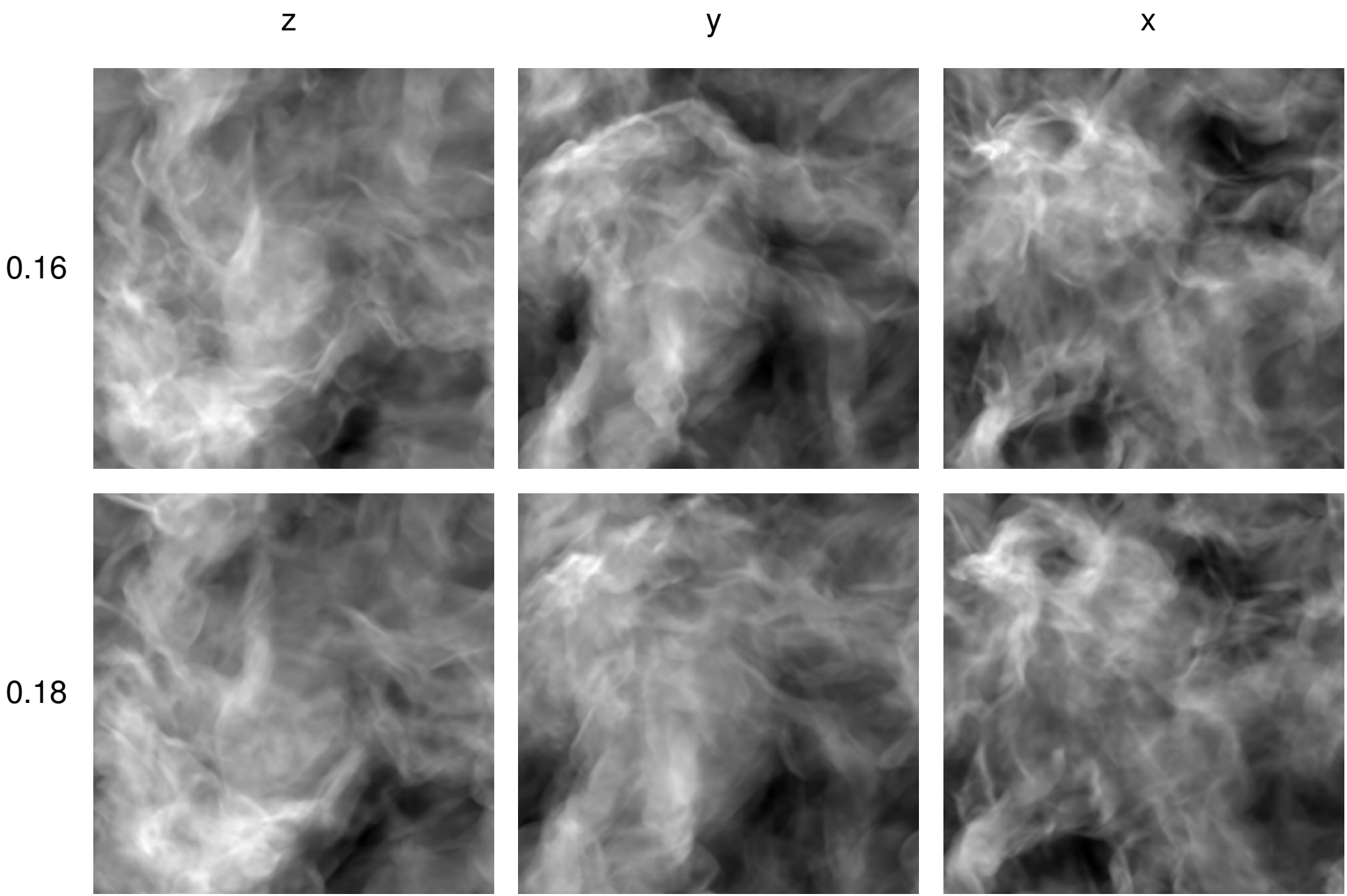
FLASH results – 256^3 gamma=1.001 column density



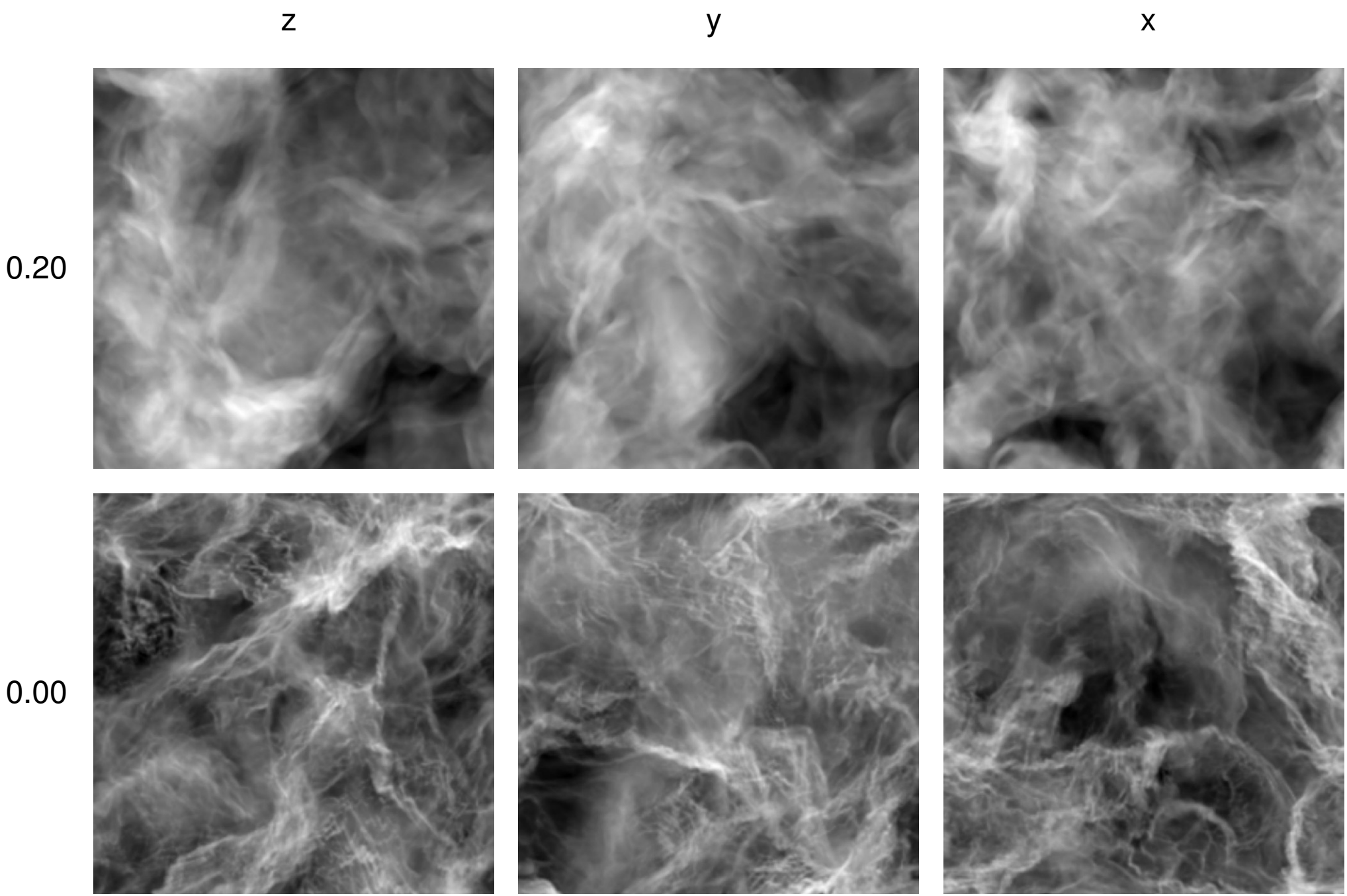
FLASH results – 256^3 gamma=1.001 column density



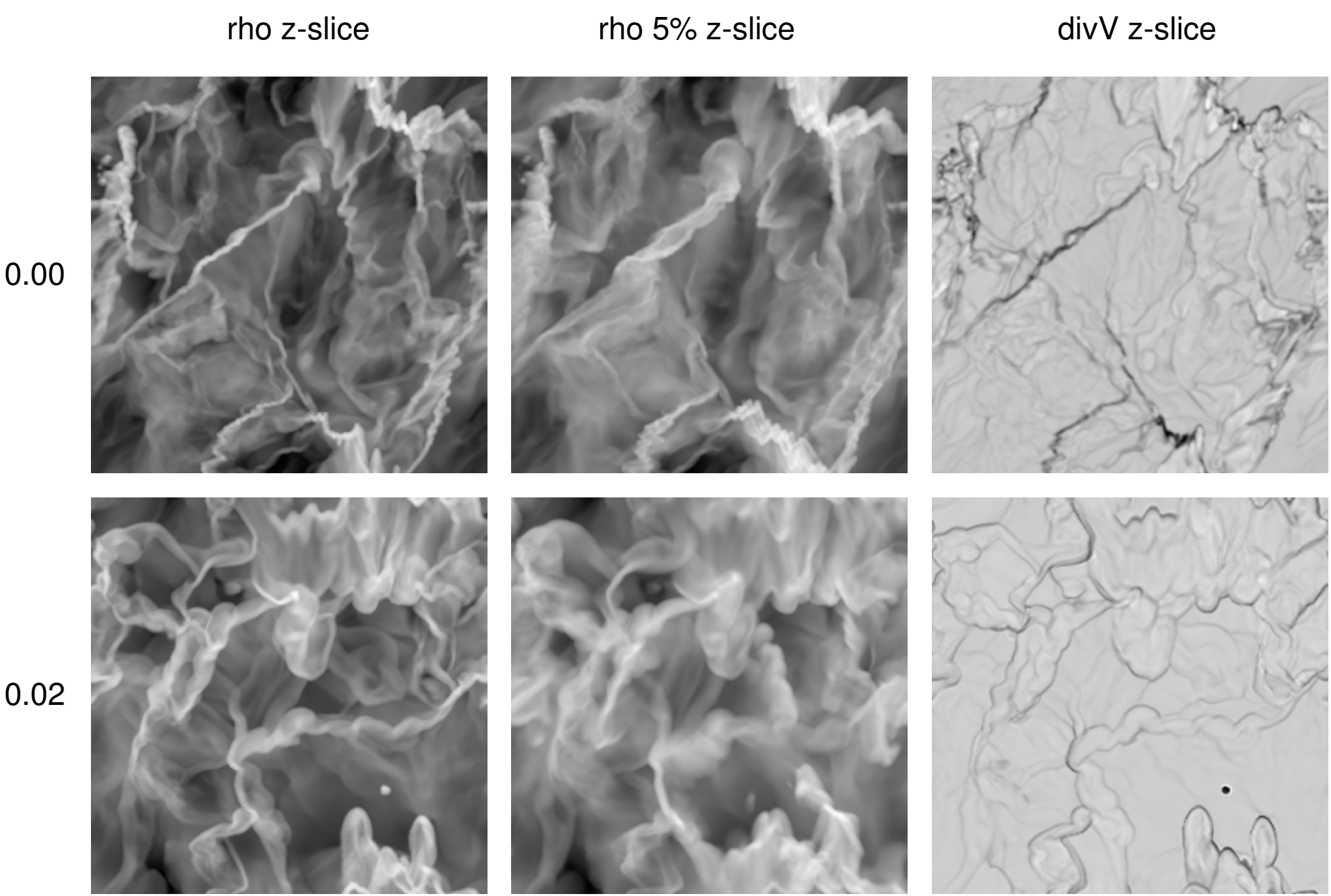
FLASH results – 256^3 gamma=1.001 column density



FLASH results – 256^3 gamma=1.001 column density



FLASH results – 256^3 gamma=1.001 rho z-slice, 5% z-slice, divV z-slice



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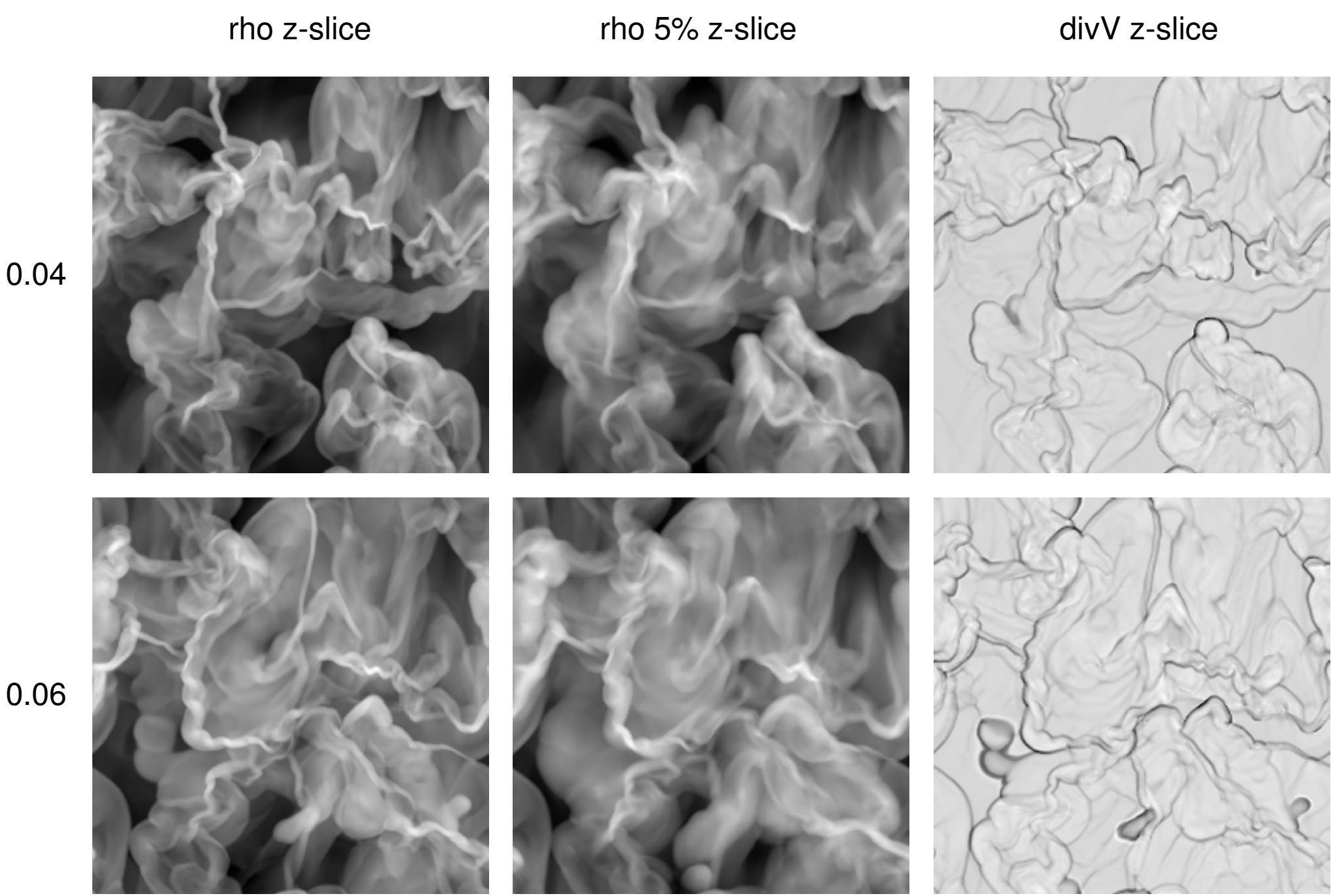
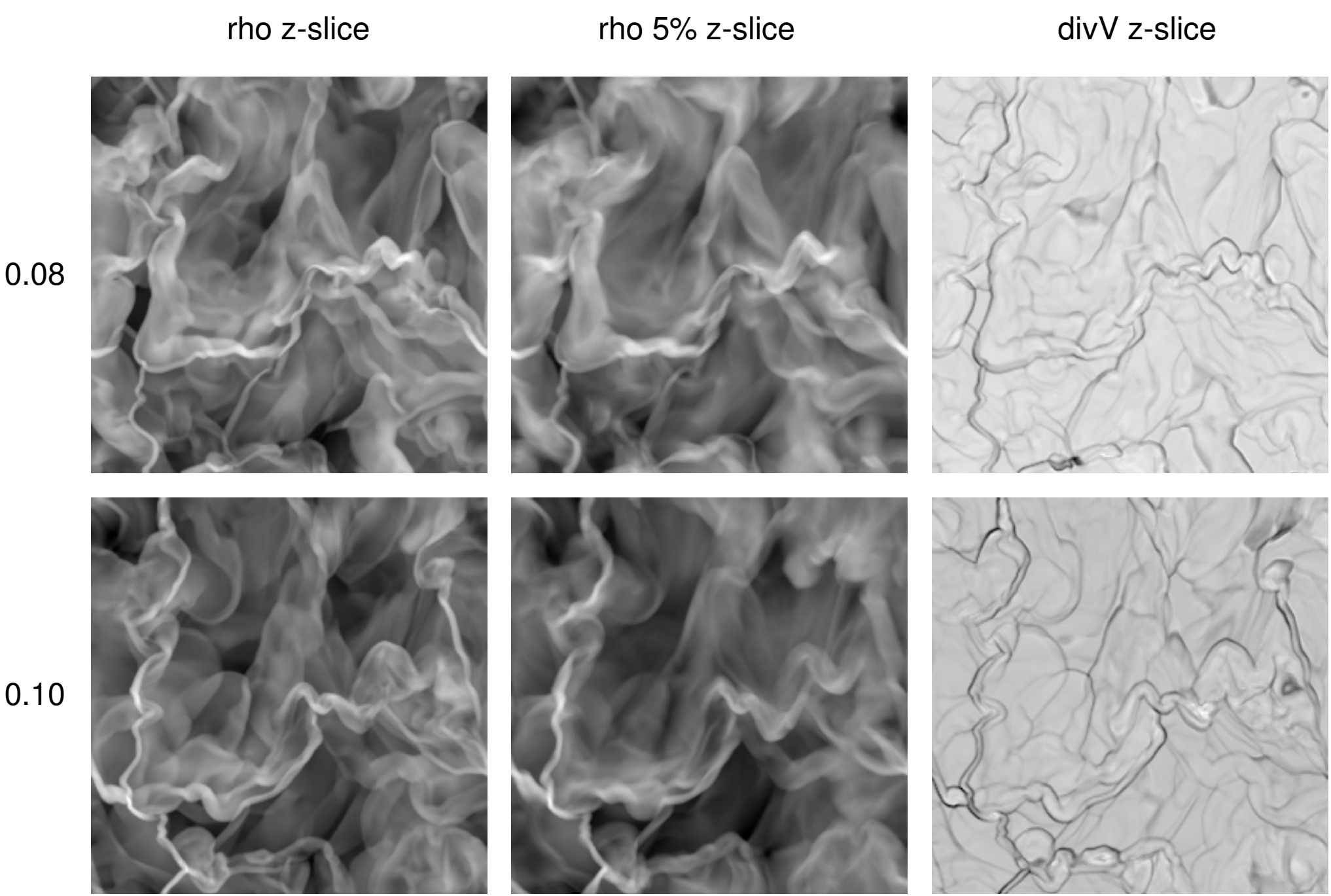
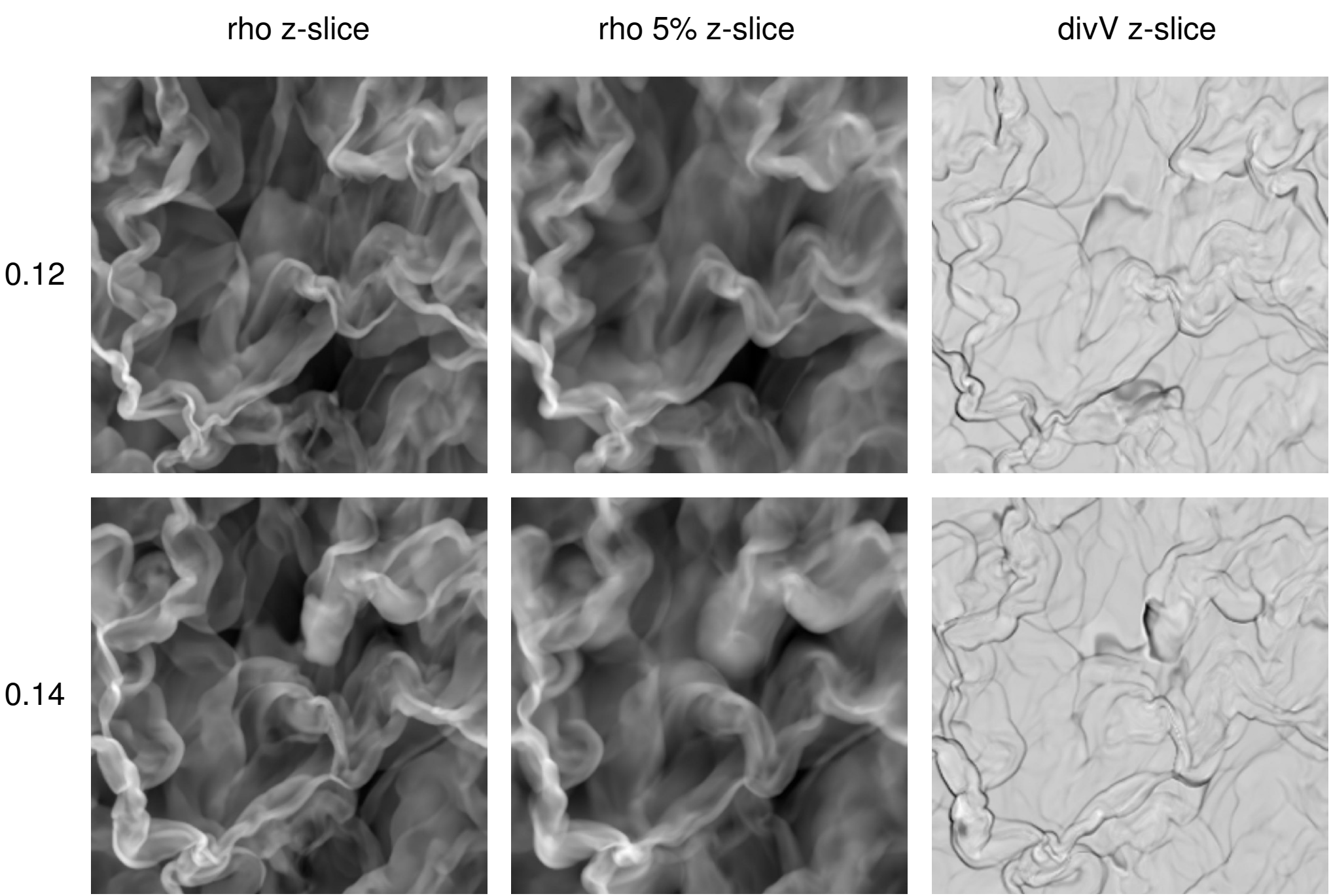


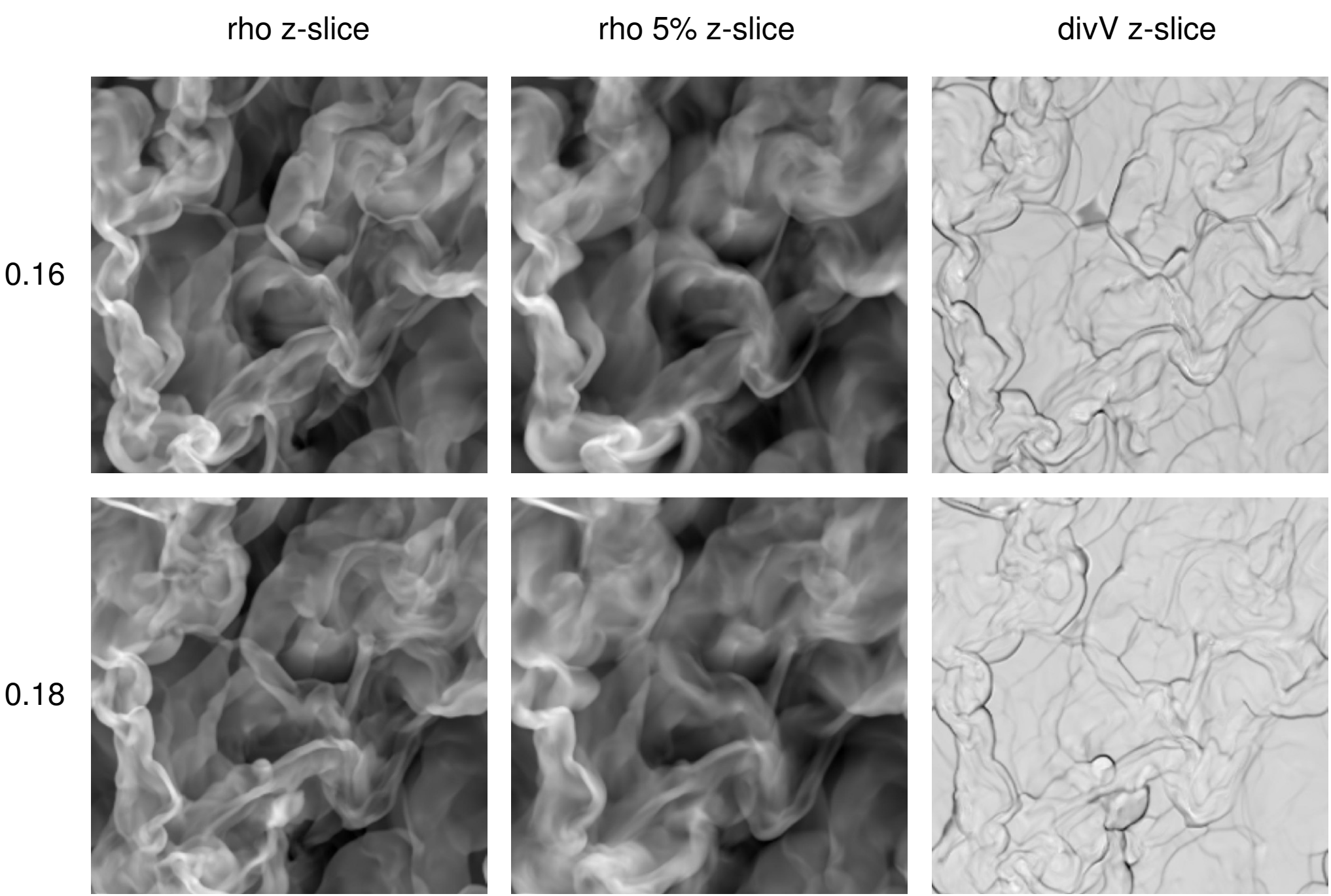
FLASH results – 256^3 gamma=1.001 rho z-slice, 5% z-slice, divV z-slice



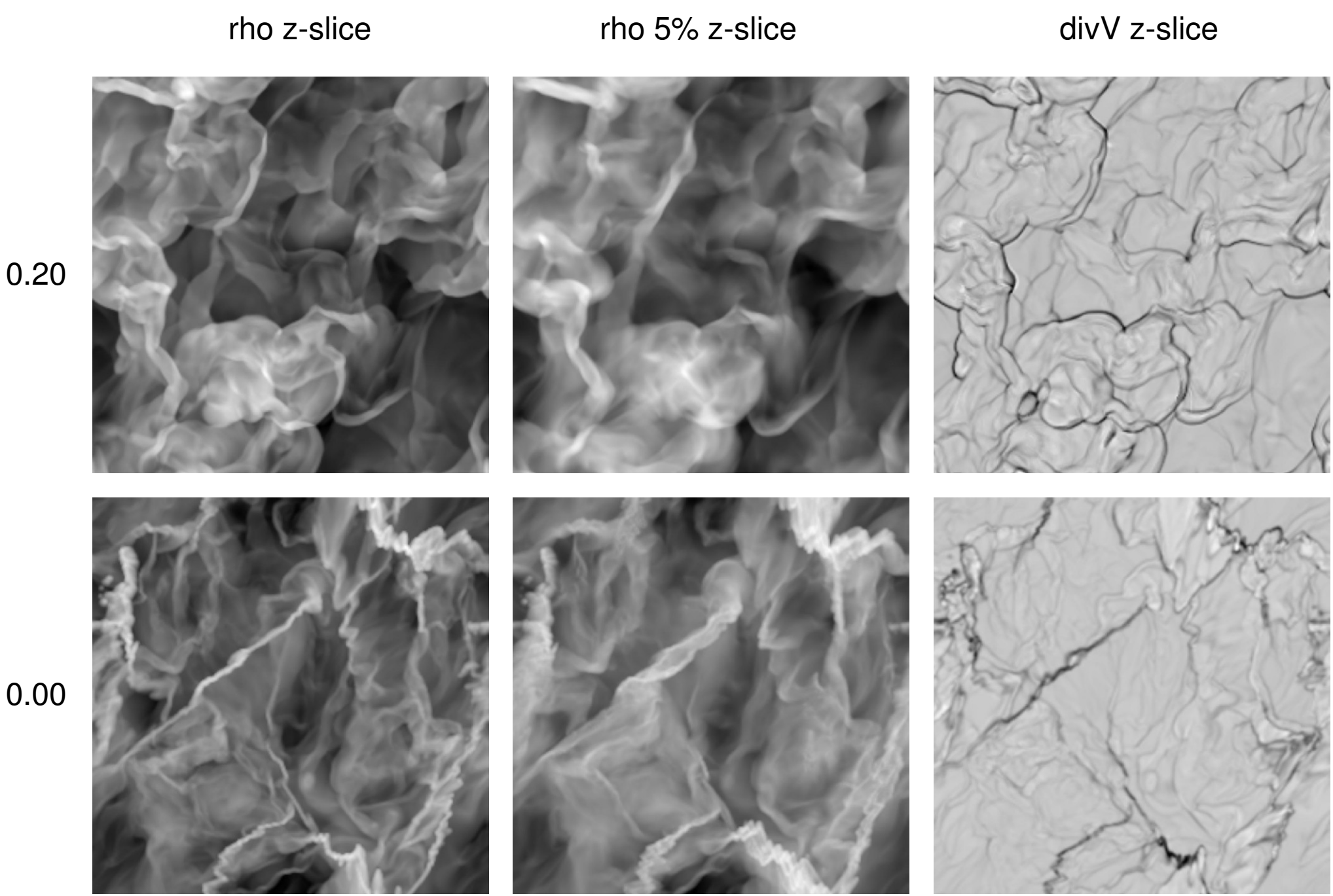
FLASH results – 256^3 gamma=1.001 rho z-slice, 5% z-slice, divV z-slice



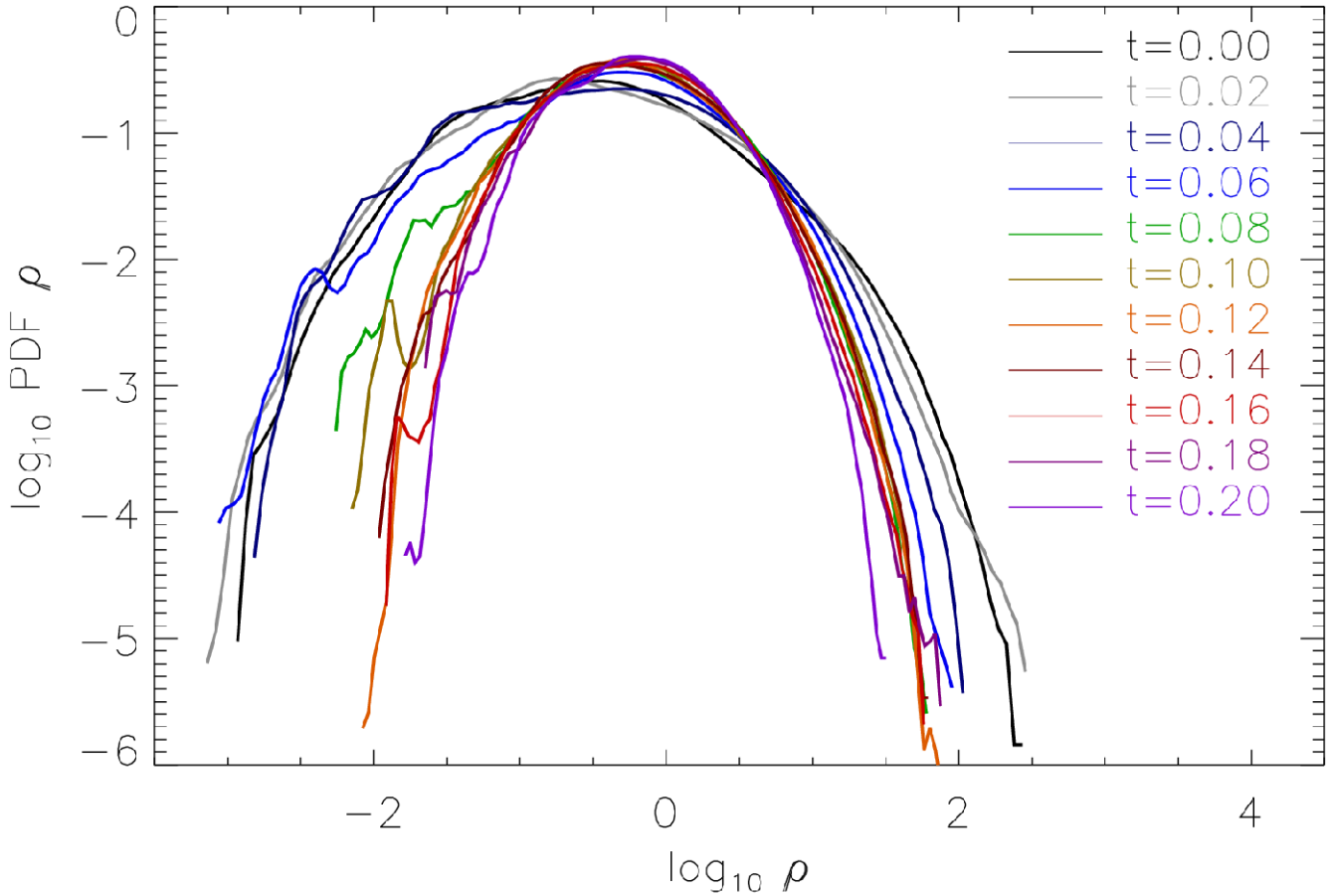
FLASH results – 256^3 gamma=1.001 rho z-slice, 5% z-slice, divV z-slice



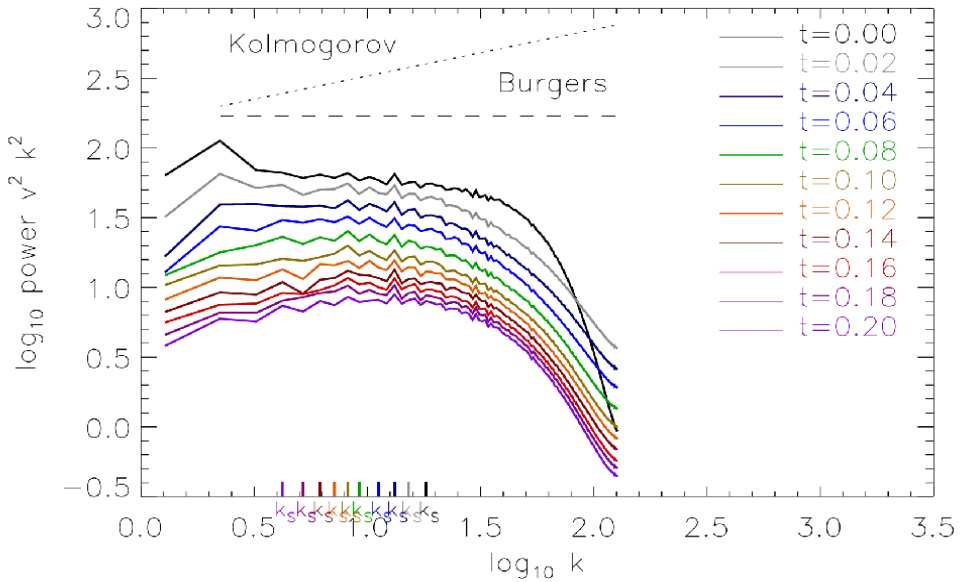
FLASH results – 256^3 gamma=1.001 rho z-slice, 5% z-slice, divV z-slice

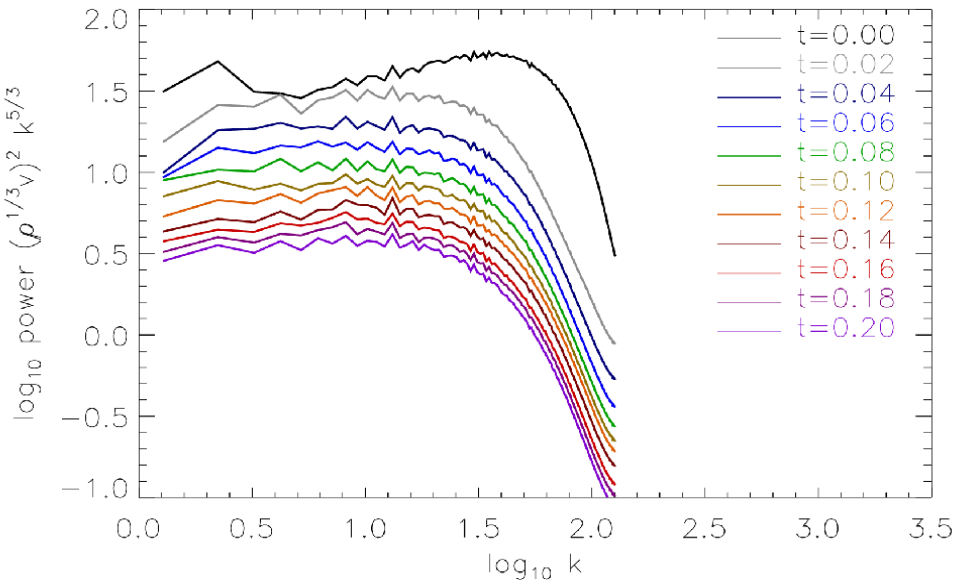


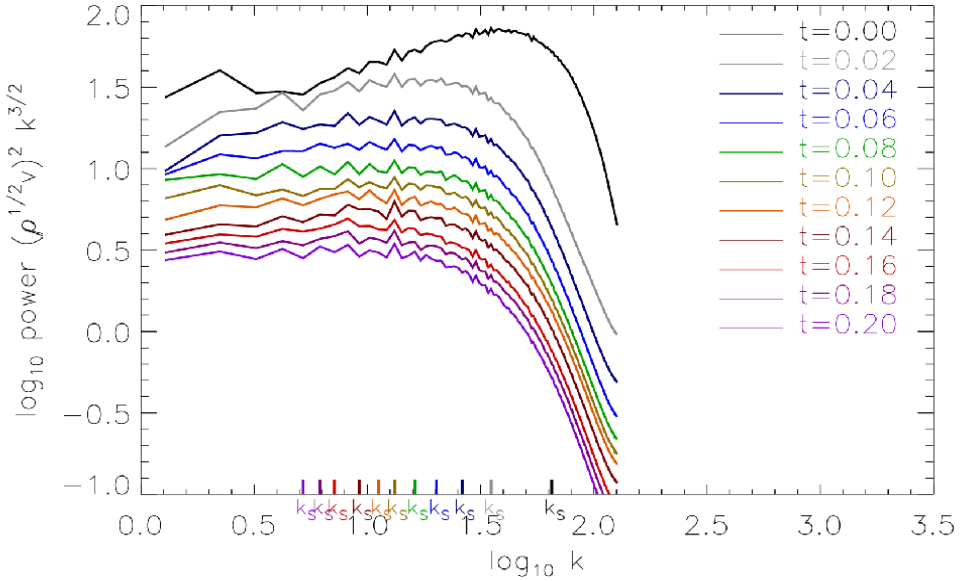
FLASH results – 256^3 gamma=1.001 density PDF

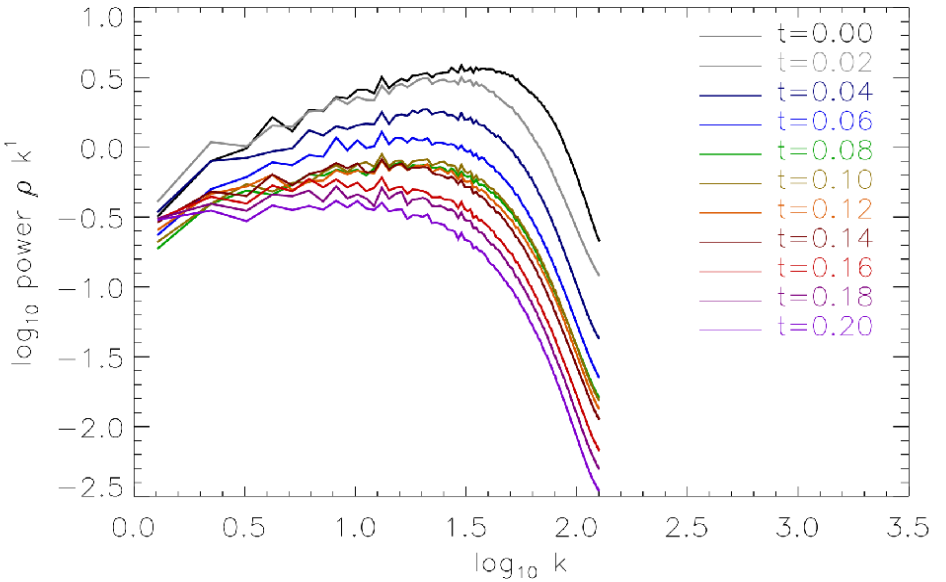


FLASH results – 256^3 gamma=1.001 power spectra



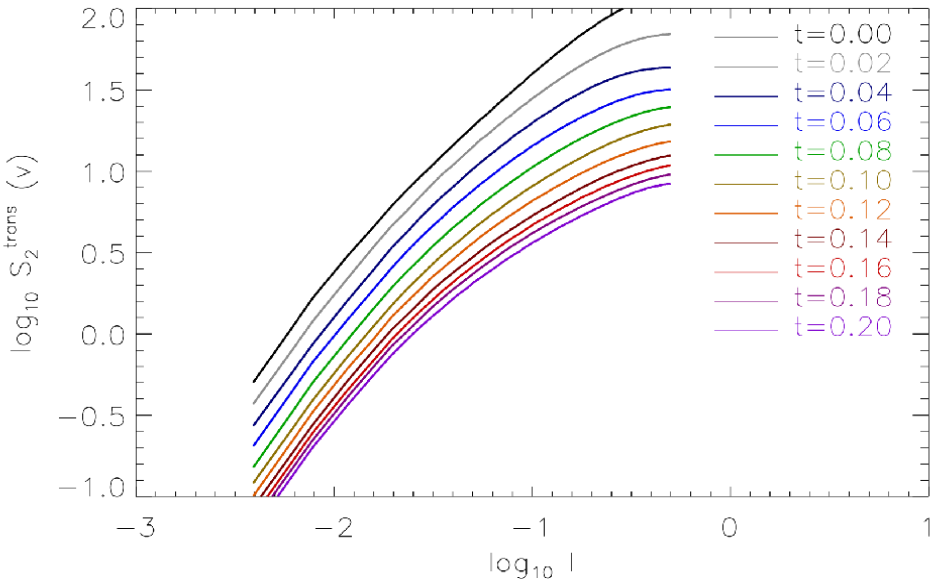




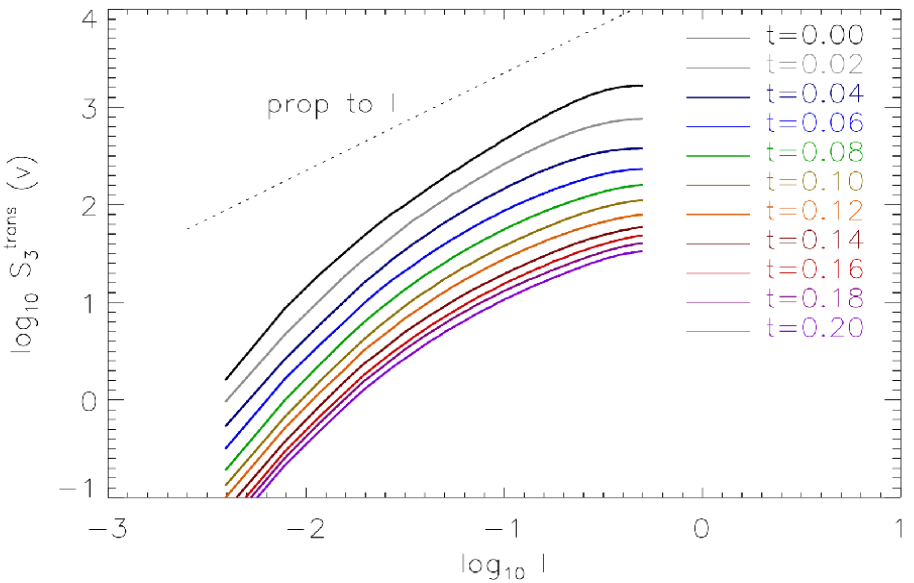


FLASH results – 256^3 gamma=1.001 structure functions

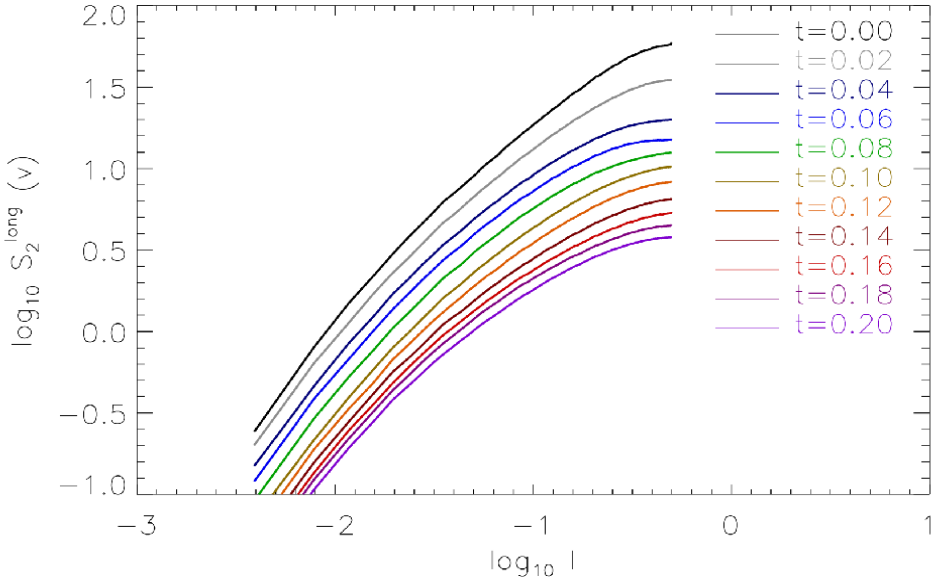
2nd order transversal



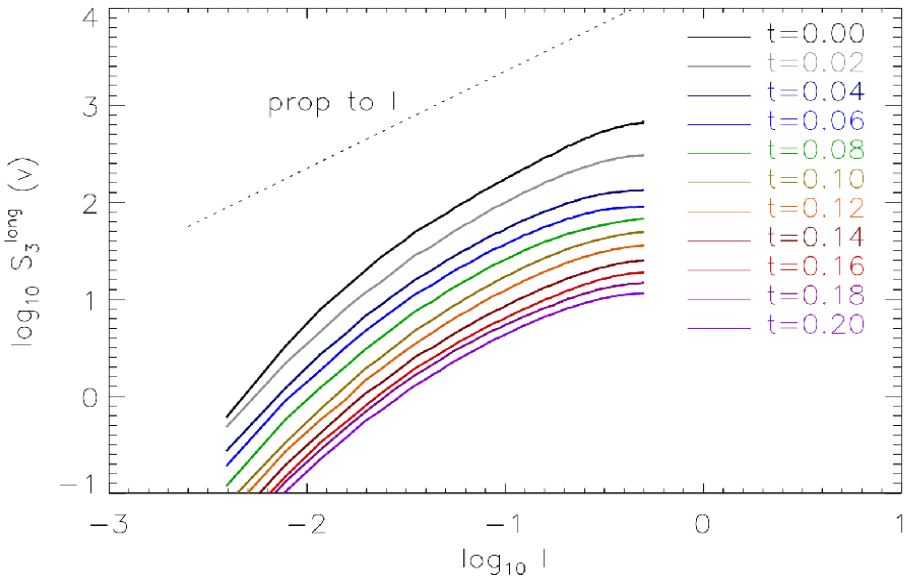
3rd order transversal



2nd order longitudinal

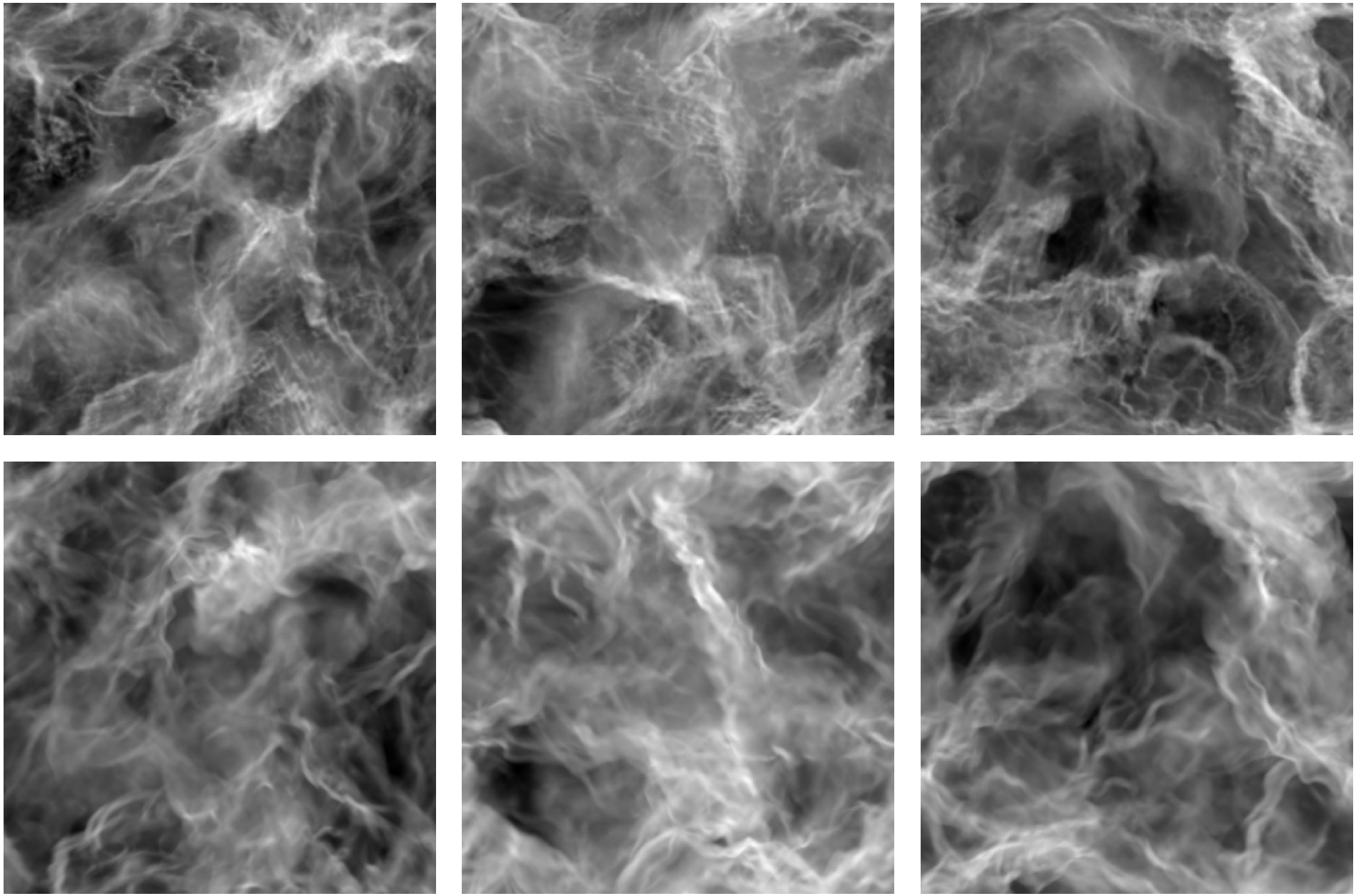


3rd order longitudinal

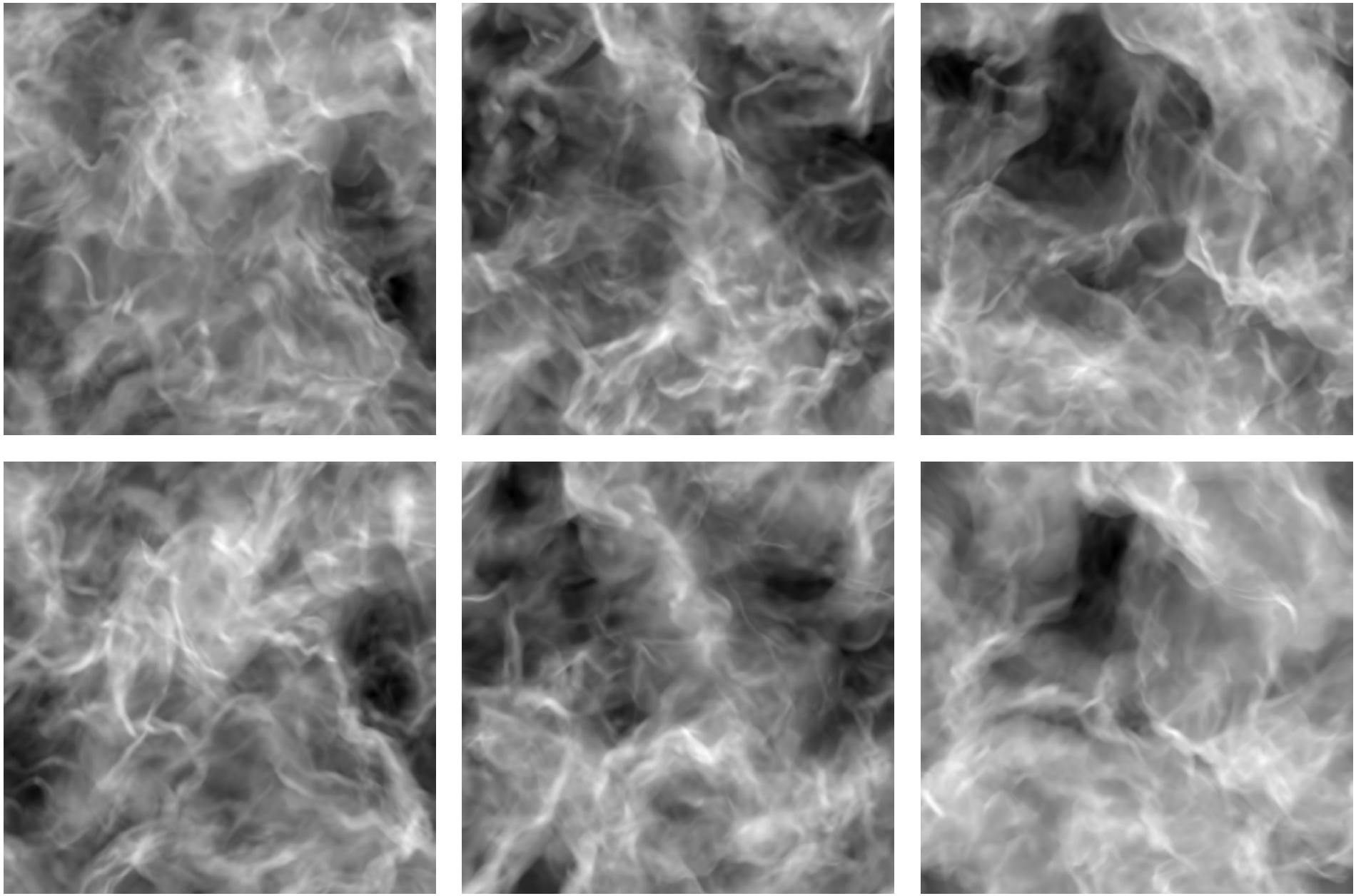


HD 256^3
with proper
isothermal equation of state

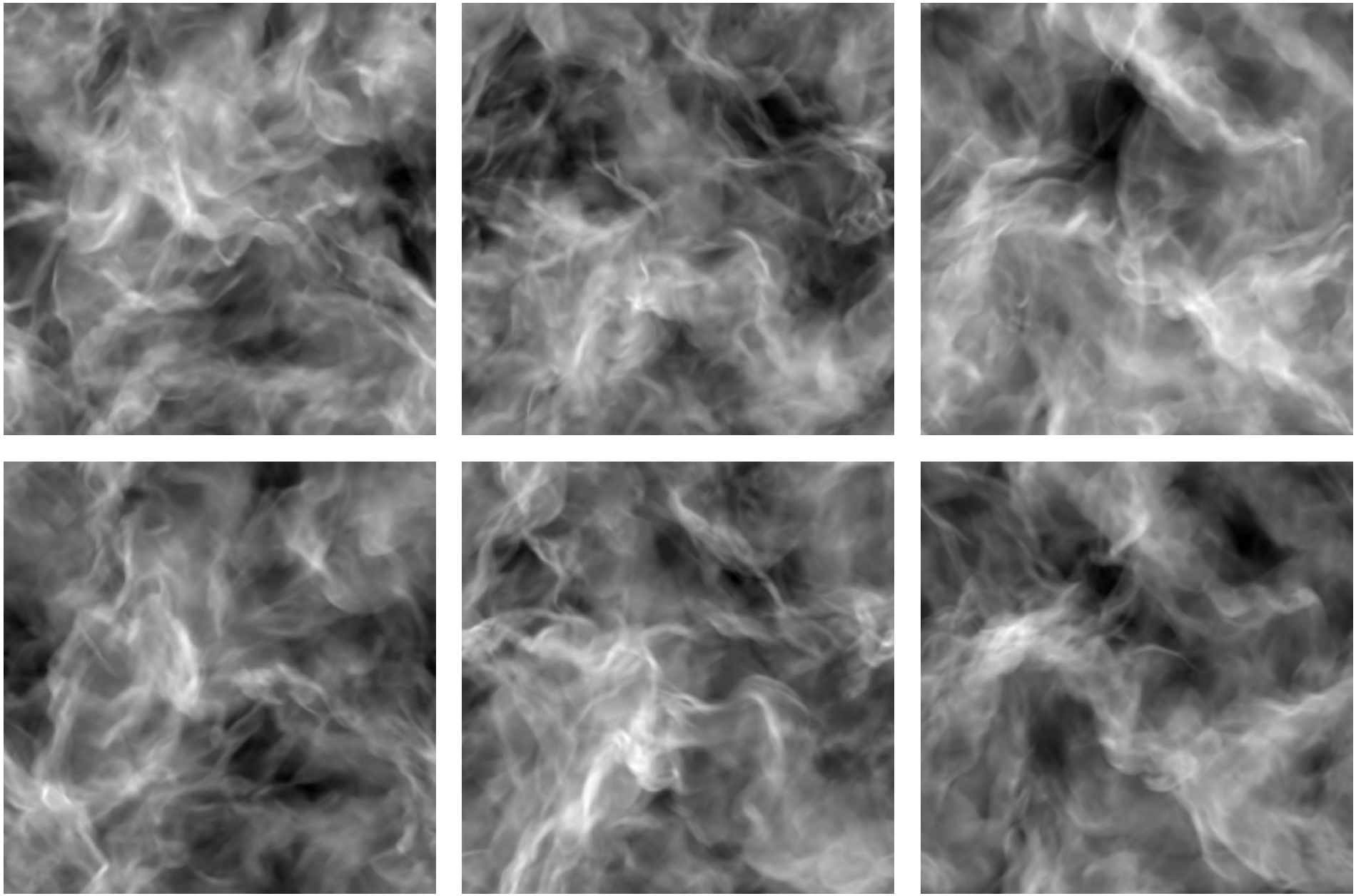
FLASH results – 256^3 polytropic eos column density



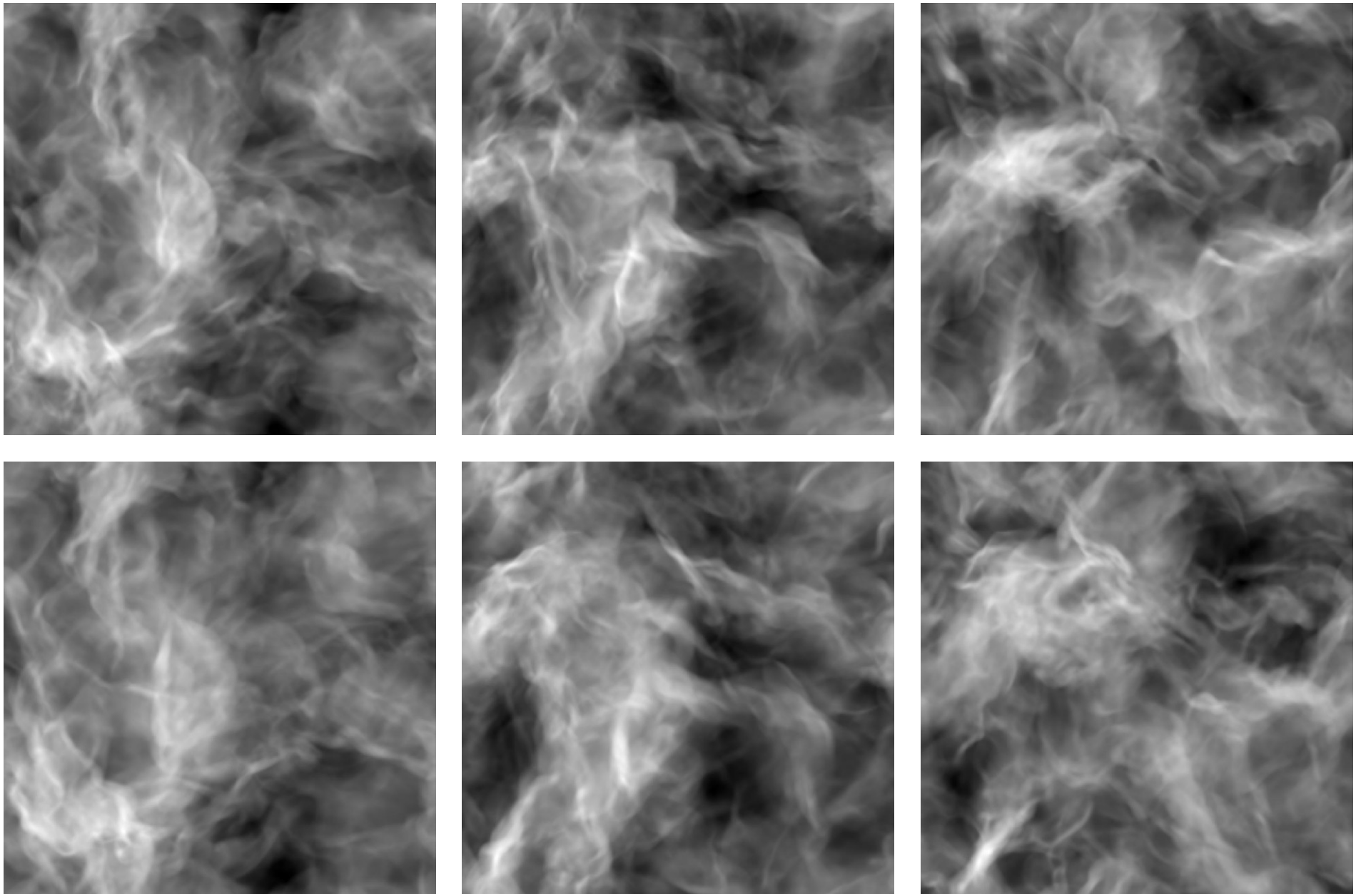
FLASH results – 256^3 polytropic eos column density



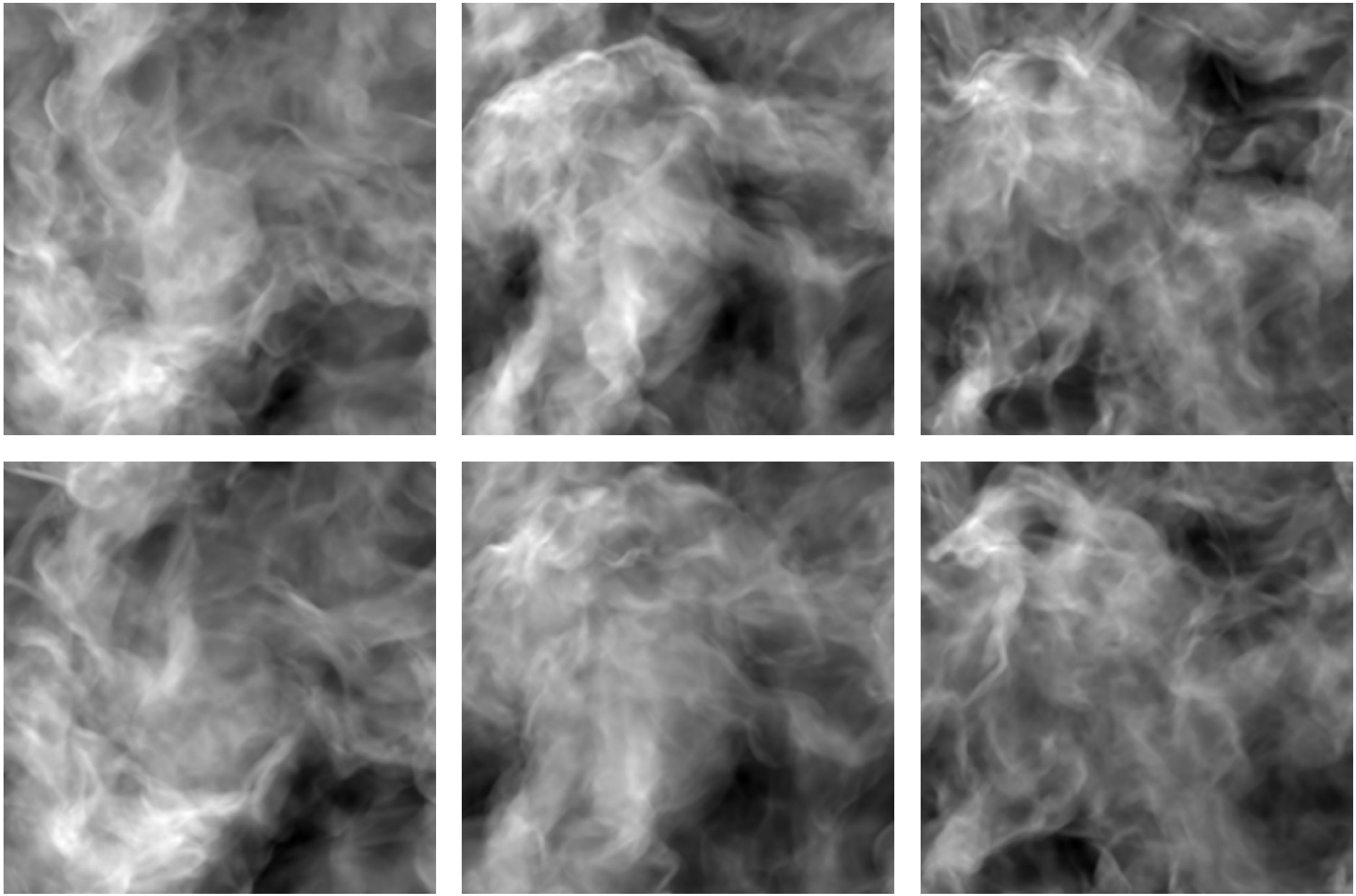
FLASH results – 256^3 polytropic eos column density



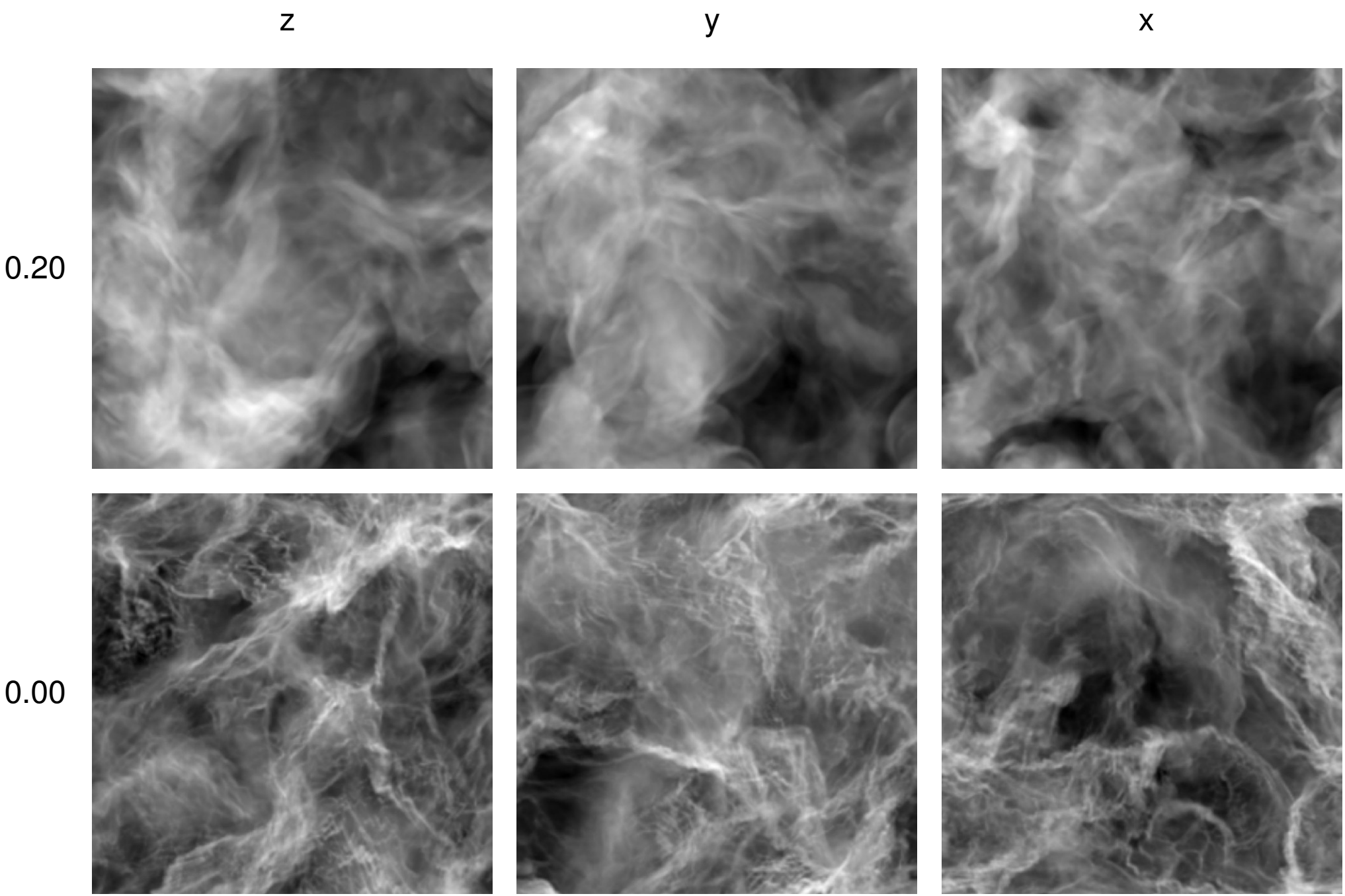
FLASH results – 256^3 polytropic eos column density



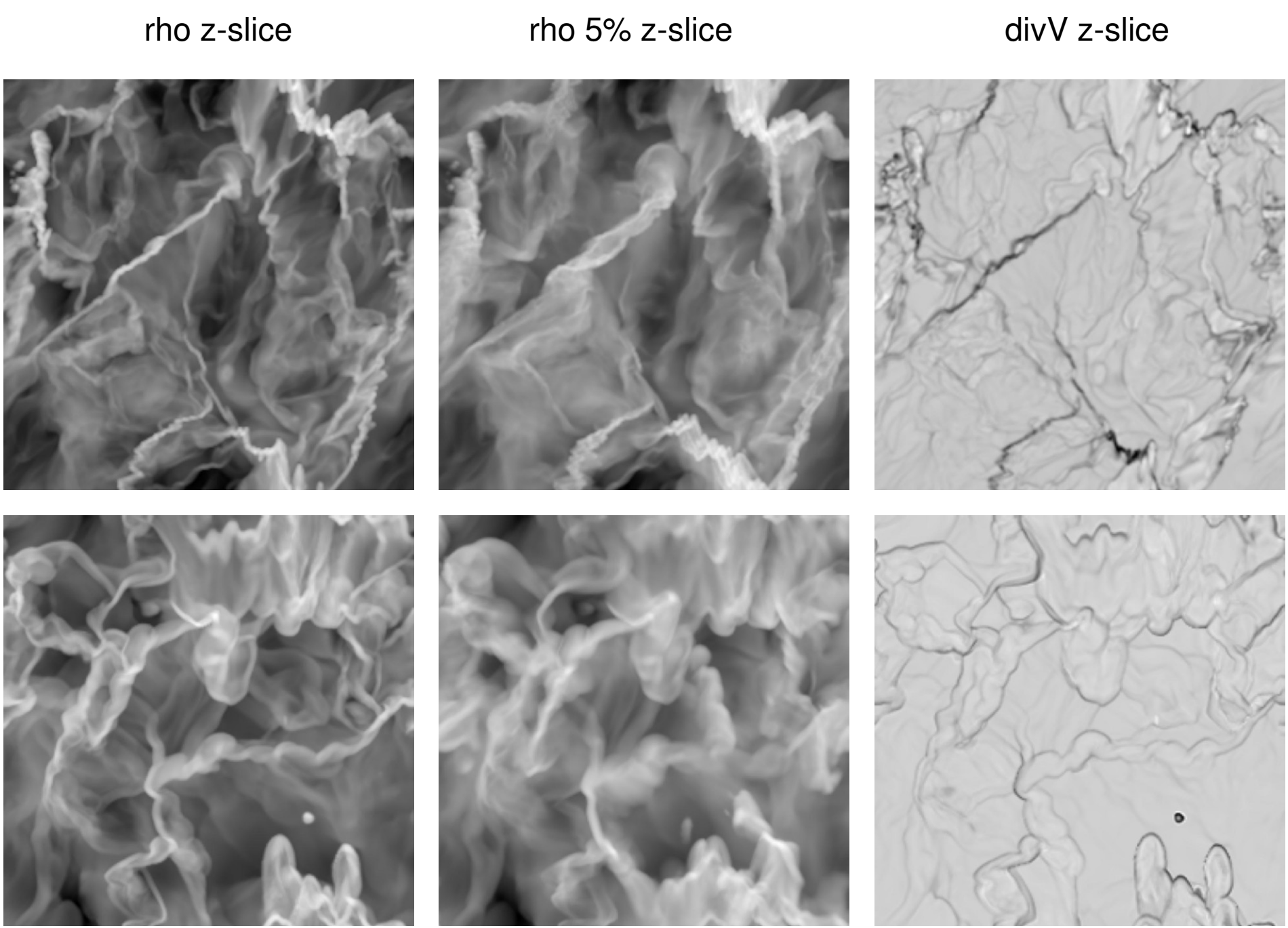
FLASH results – 256^3 polytropic eos column density



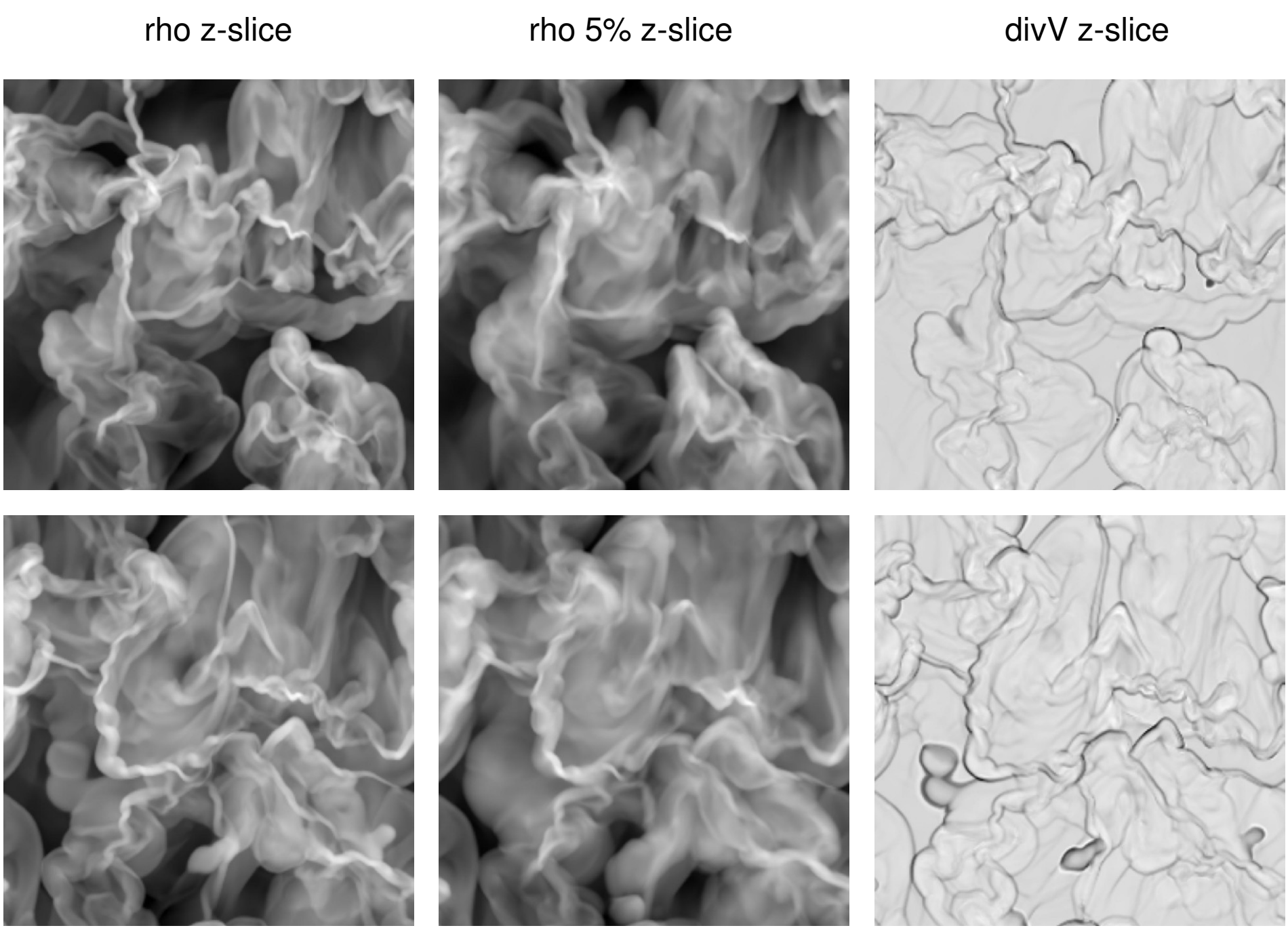
FLASH results – 256^3 polytropic eos column density



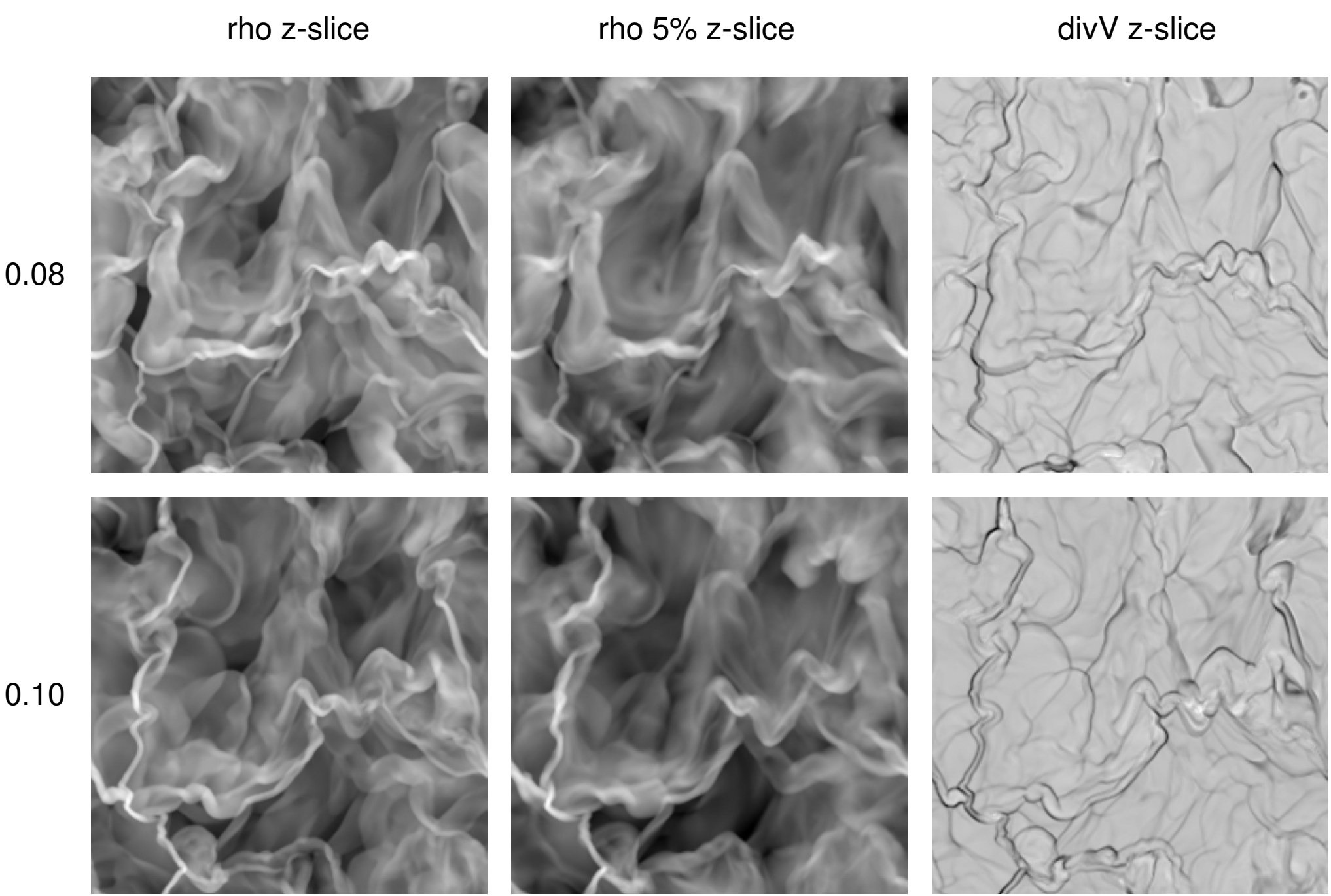
FLASH results – 256^3 polytropic eos rho z-slice, 5% z-slice, divV z-slice



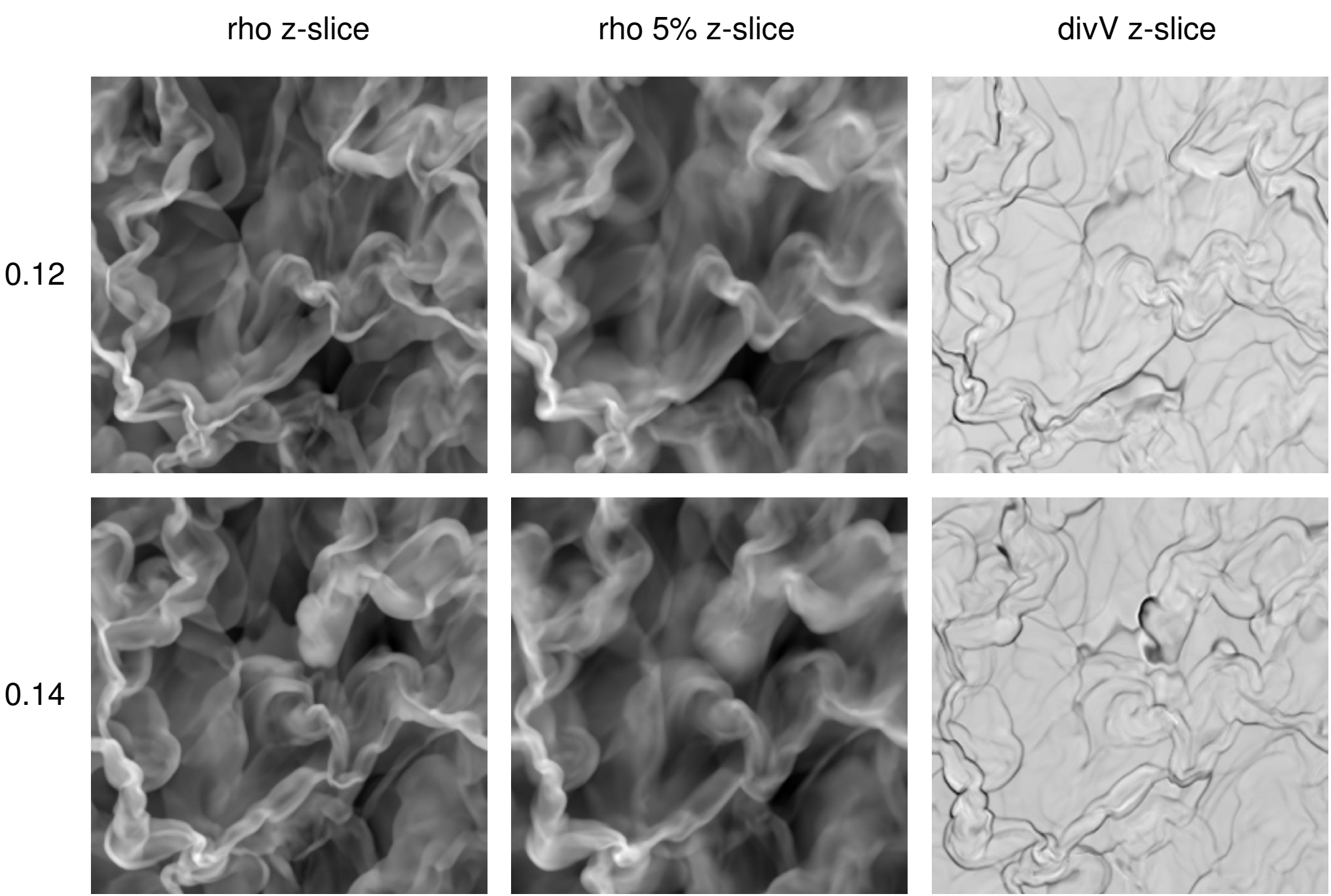
FLASH results – 256^3 polytropic eos rho z-slice, 5% z-slice, divV z-slice



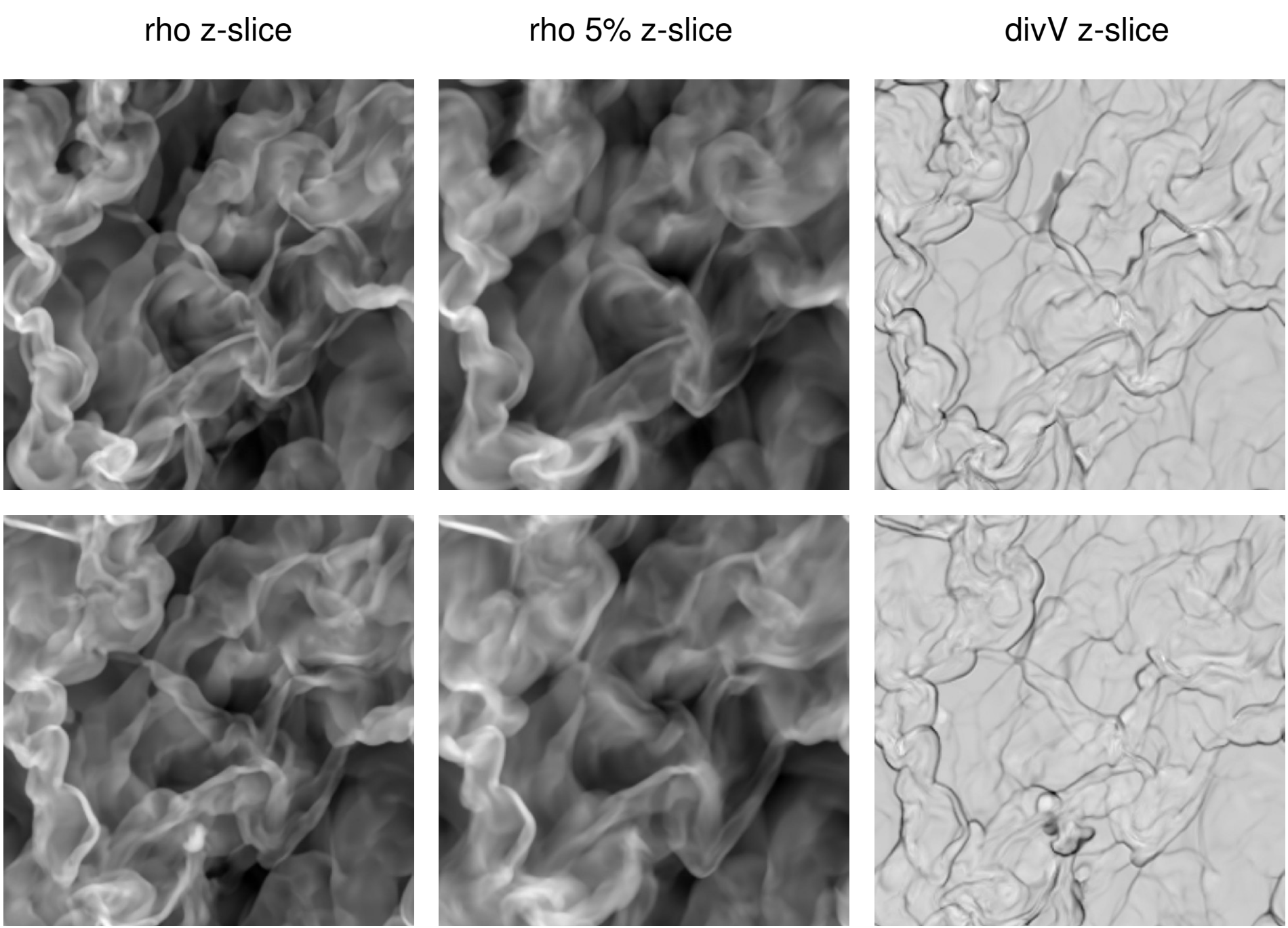
FLASH results – 256^3 polytropic eos rho z-slice, 5% z-slice, divV z-slice



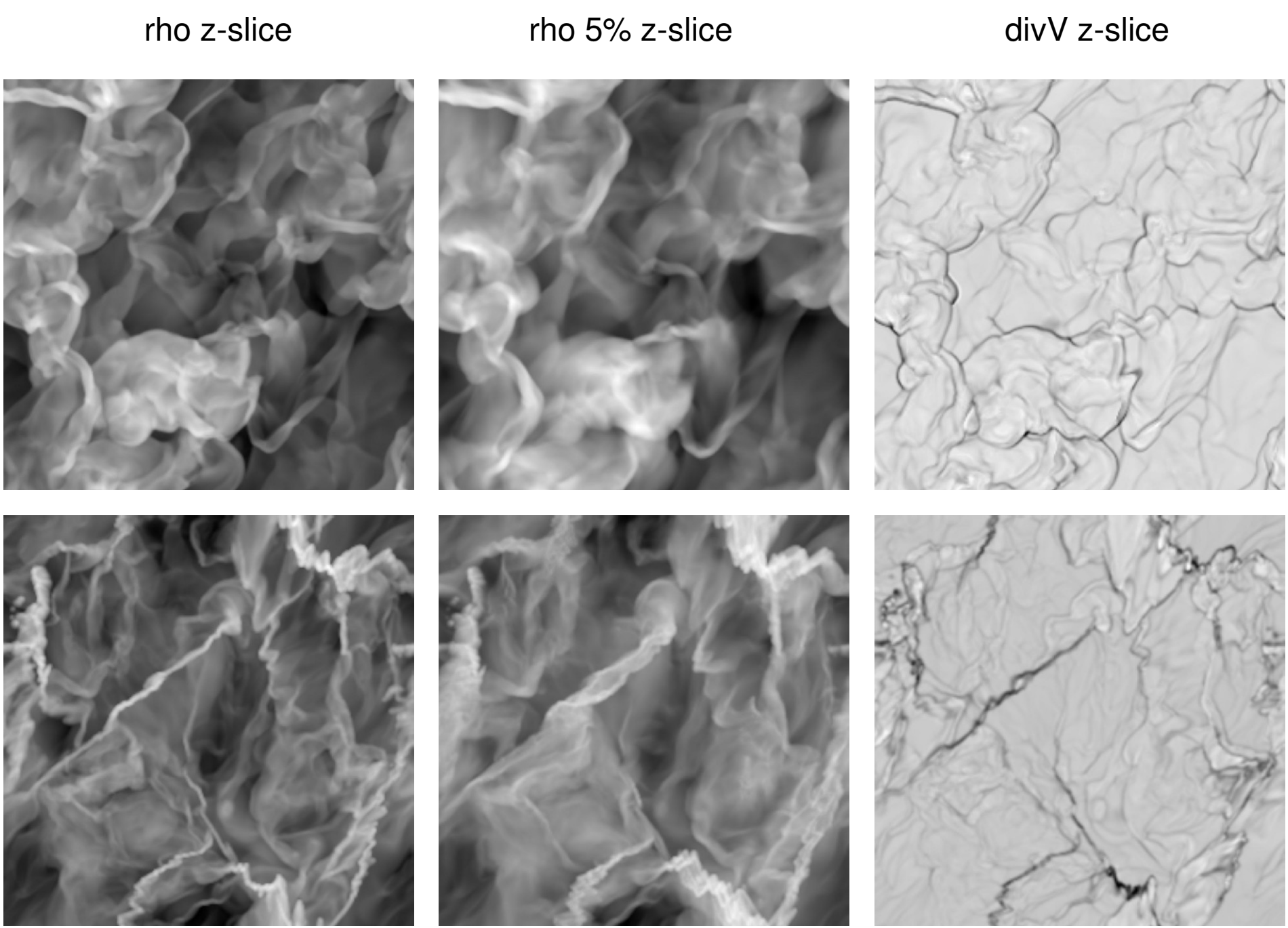
FLASH results – 256^3 polytropic eos rho z-slice, 5% z-slice, divV z-slice



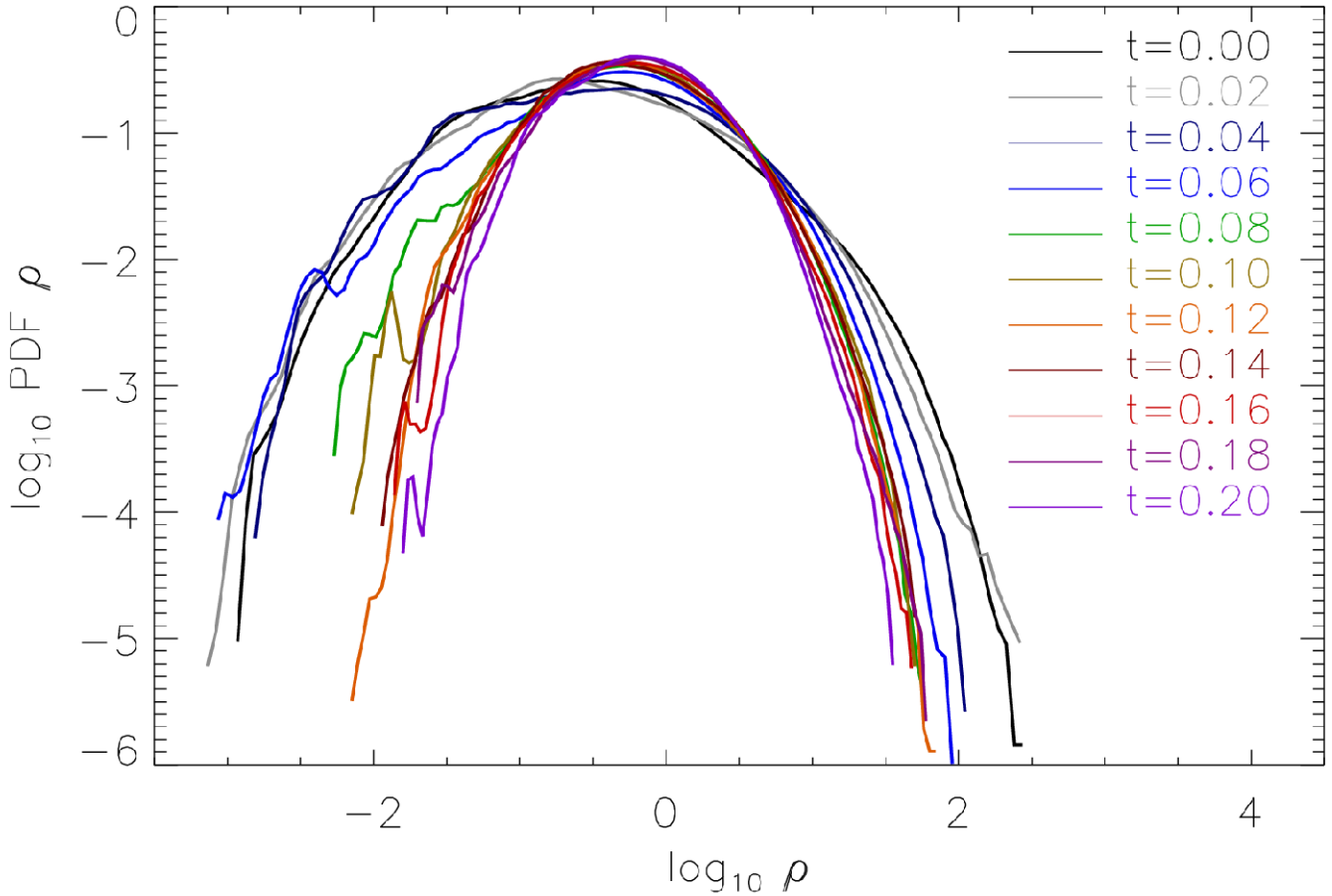
FLASH results – 256^3 polytropic eos rho z-slice, 5% z-slice, divV z-slice



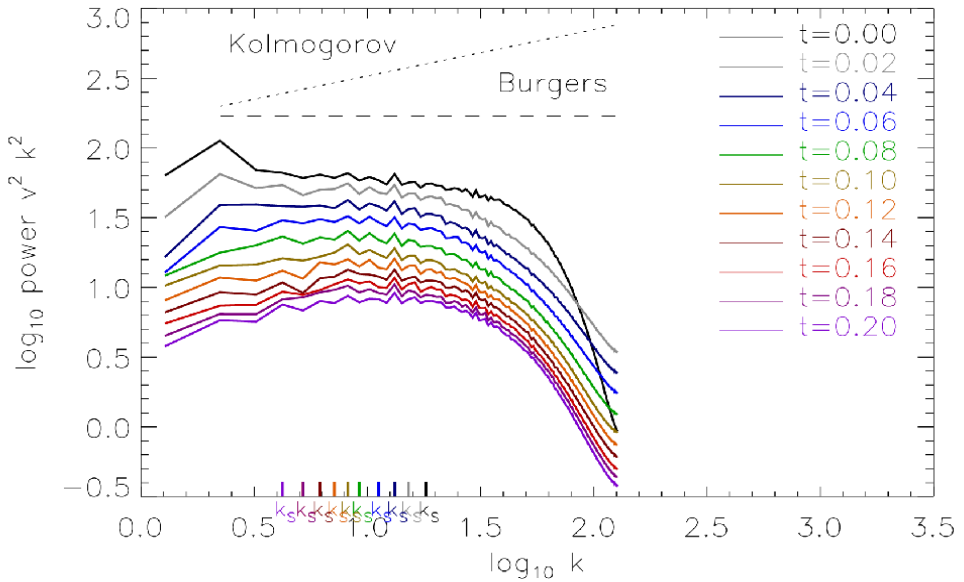
FLASH results – 256^3 polytropic eos rho z-slice, 5% z-slice, divV z-slice

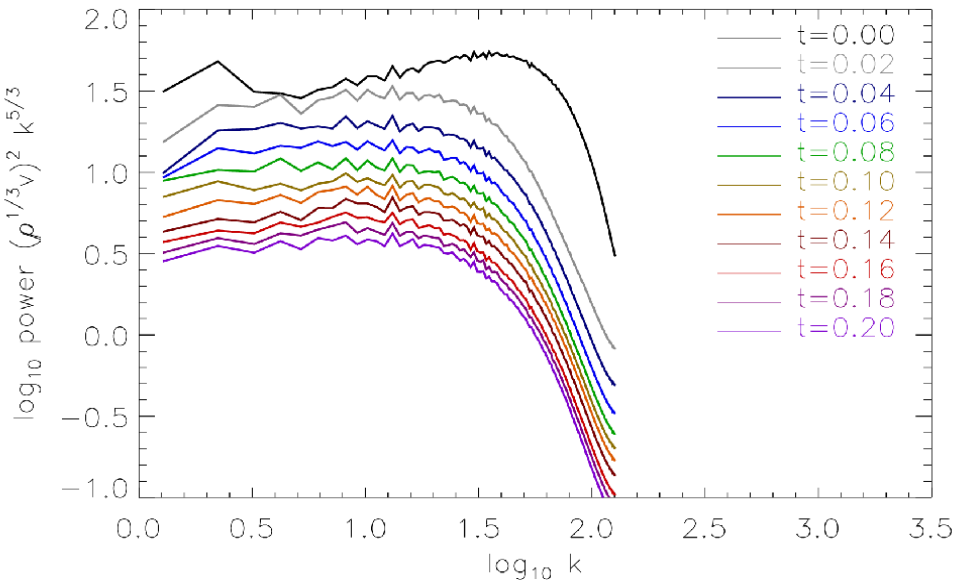


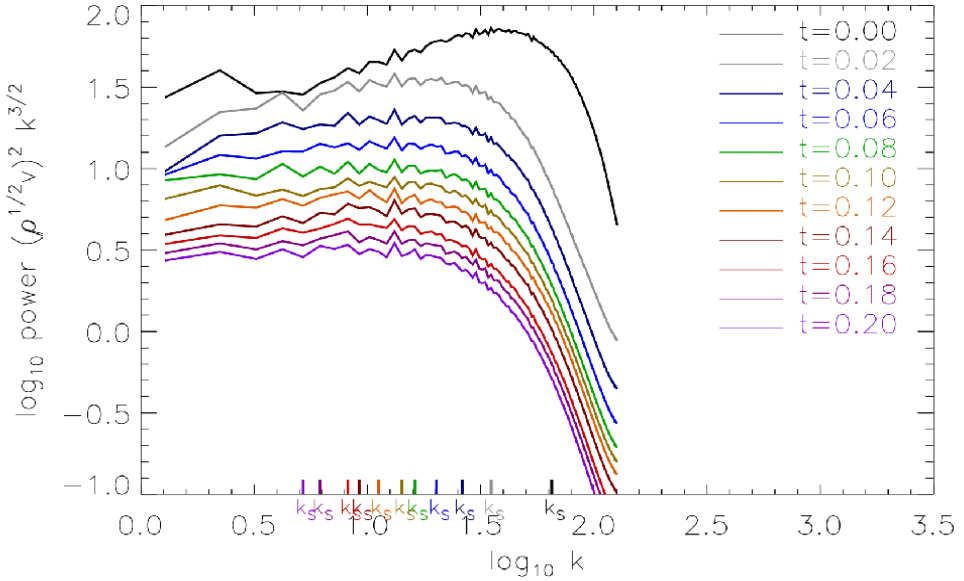
FLASH results – 256^3 polytropic eos density PDF

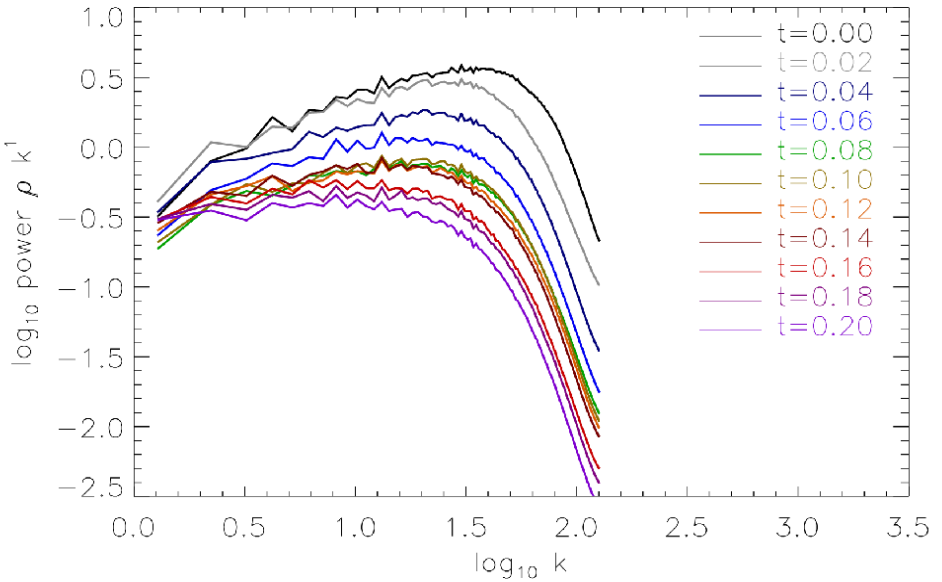


FLASH results – 256^3 polytropic eos power spectra



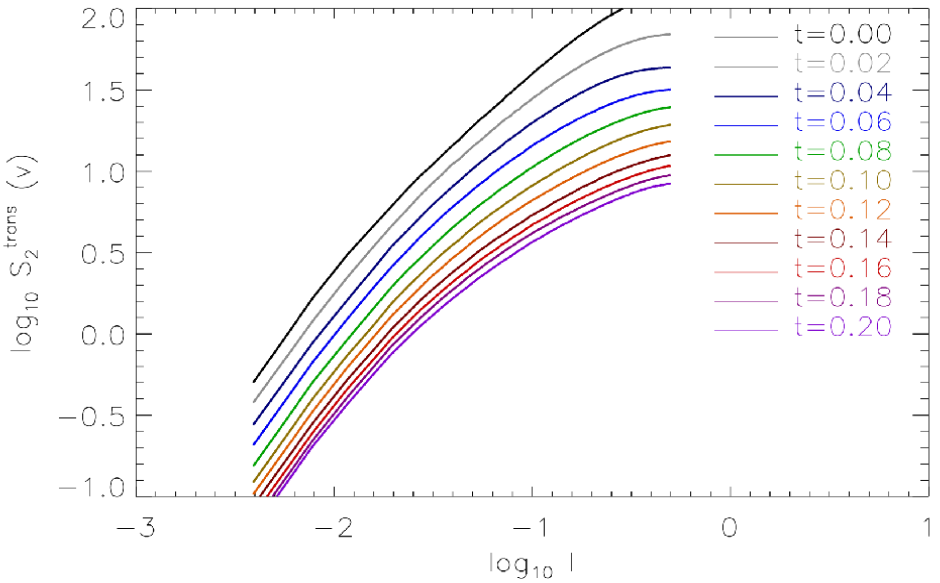




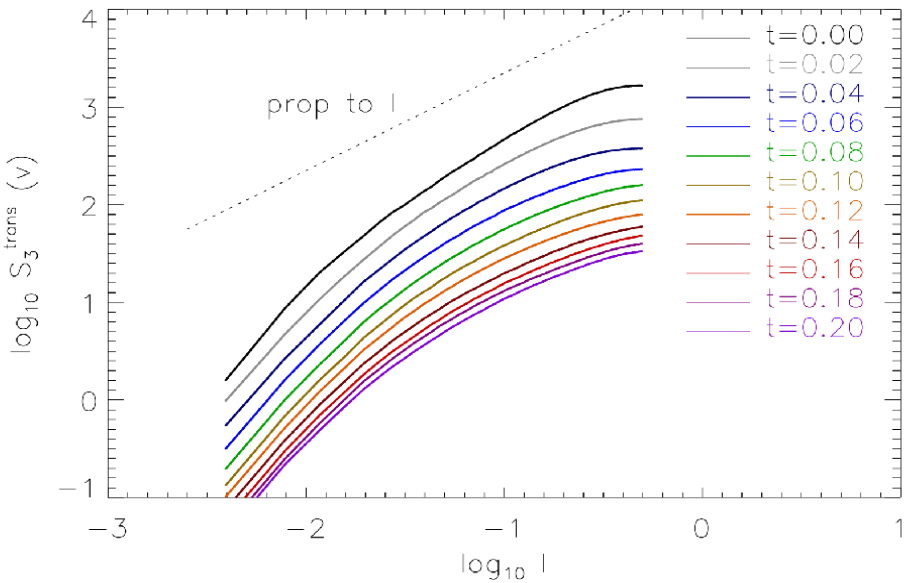


FLASH results – 256^3 polytropic eos structure functions

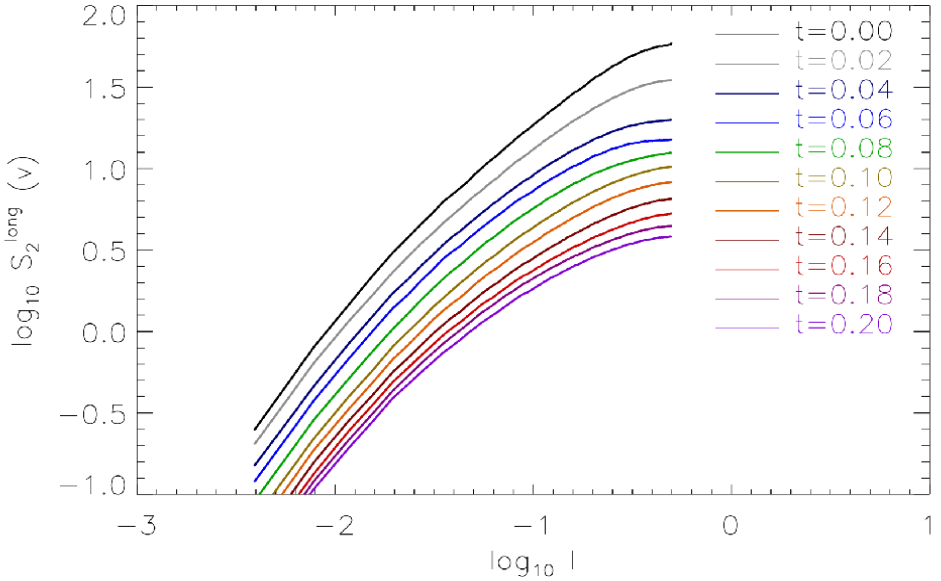
2nd order transversal



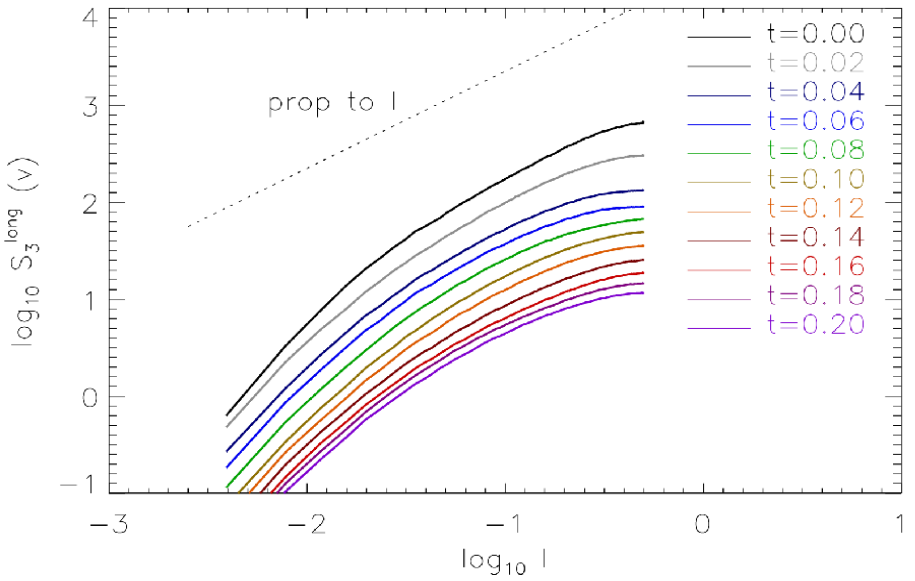
3rd order transversal



2nd order longitudinal

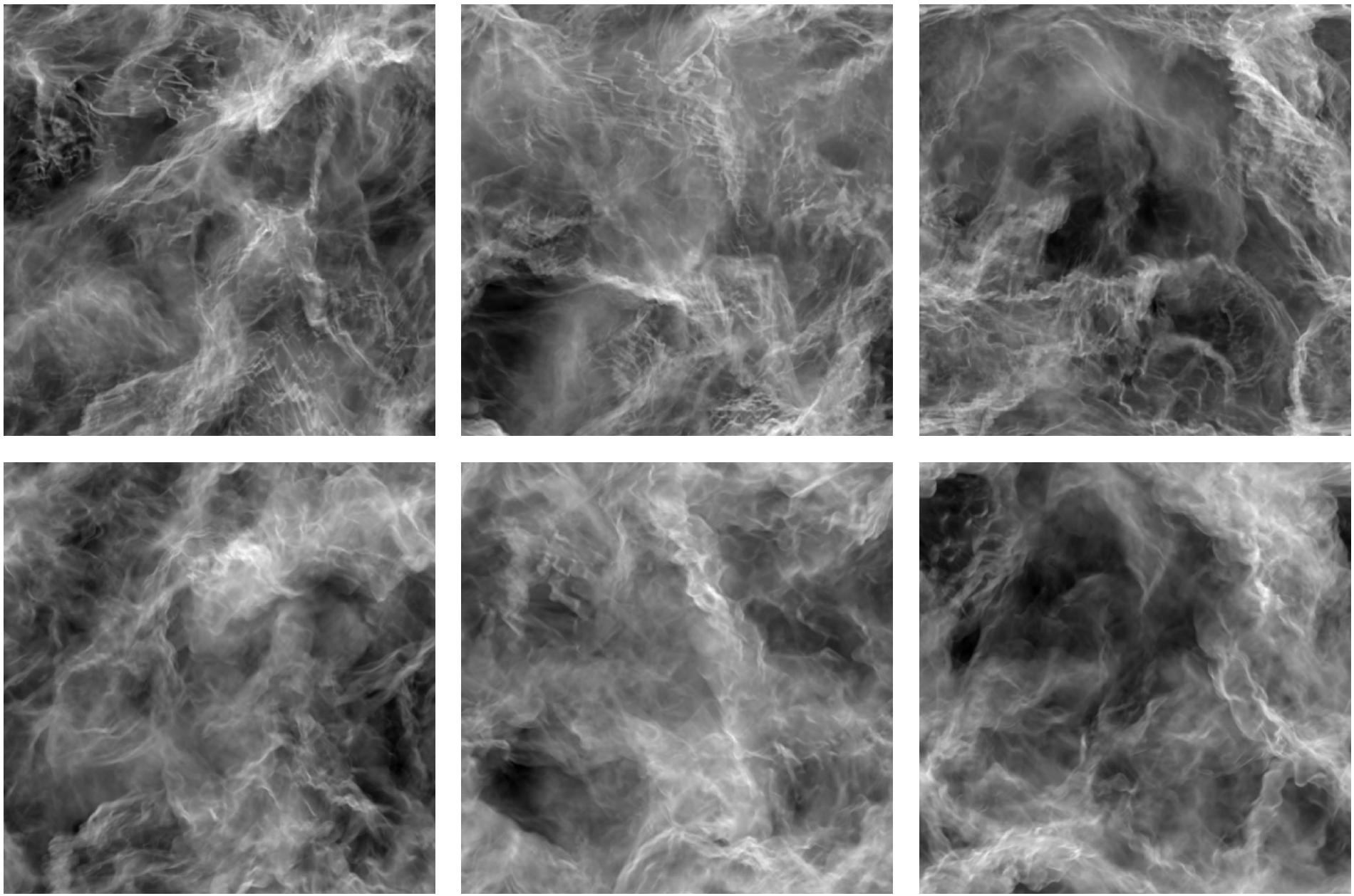


3rd order longitudinal

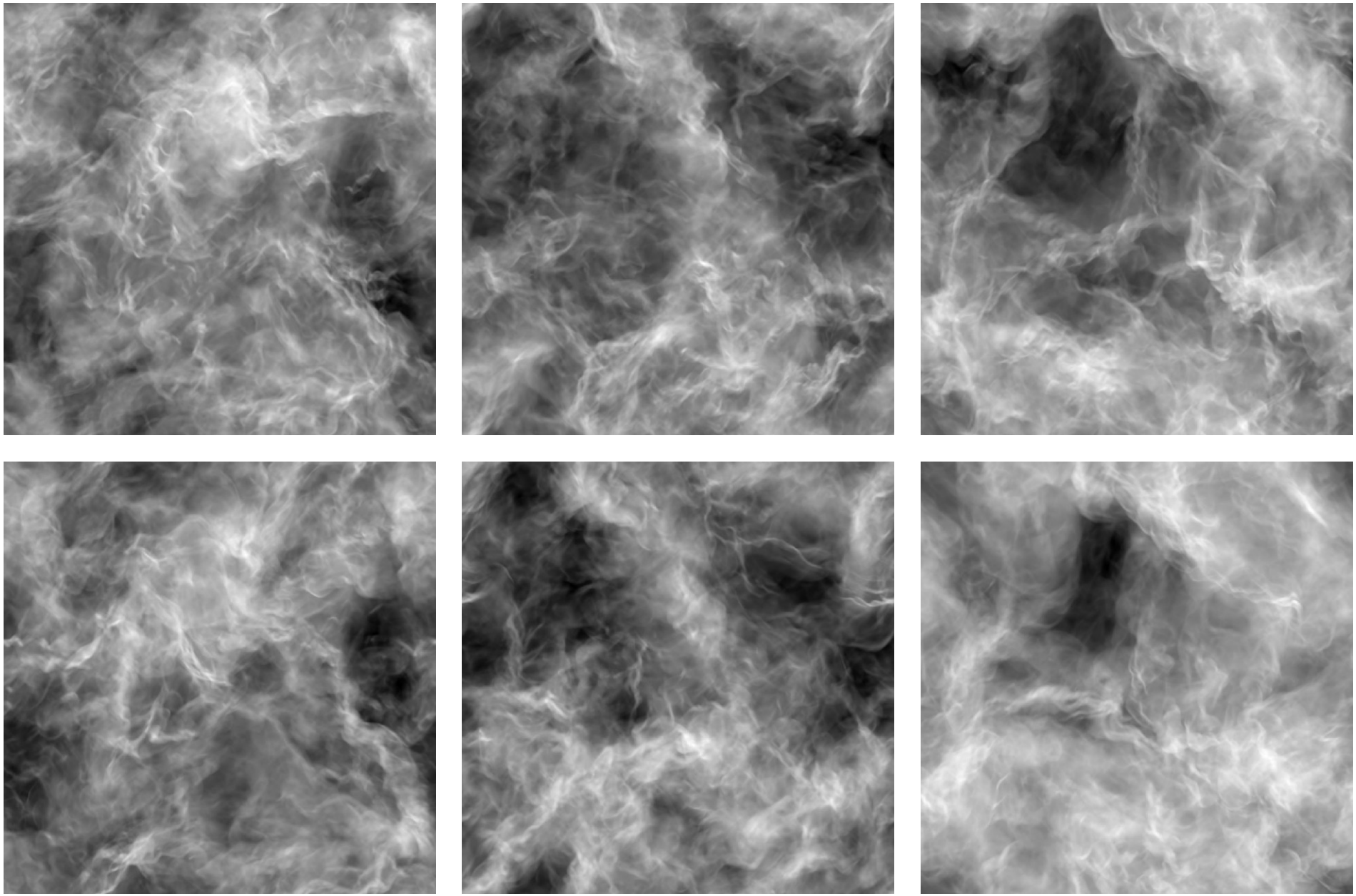


HD 512^3
with proper
isothermal equation of state

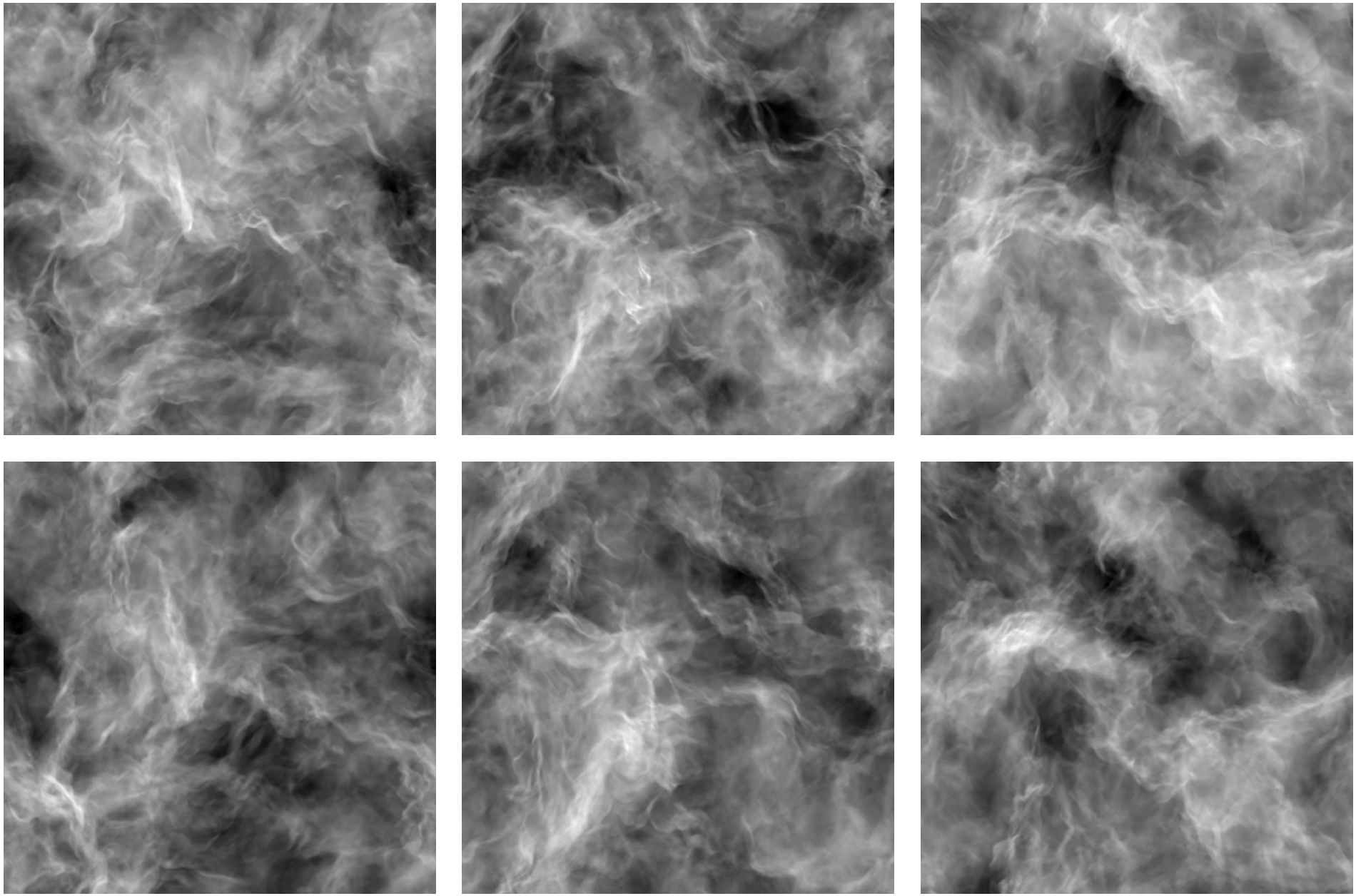
FLASH results – 512^3 polytropic eos column density



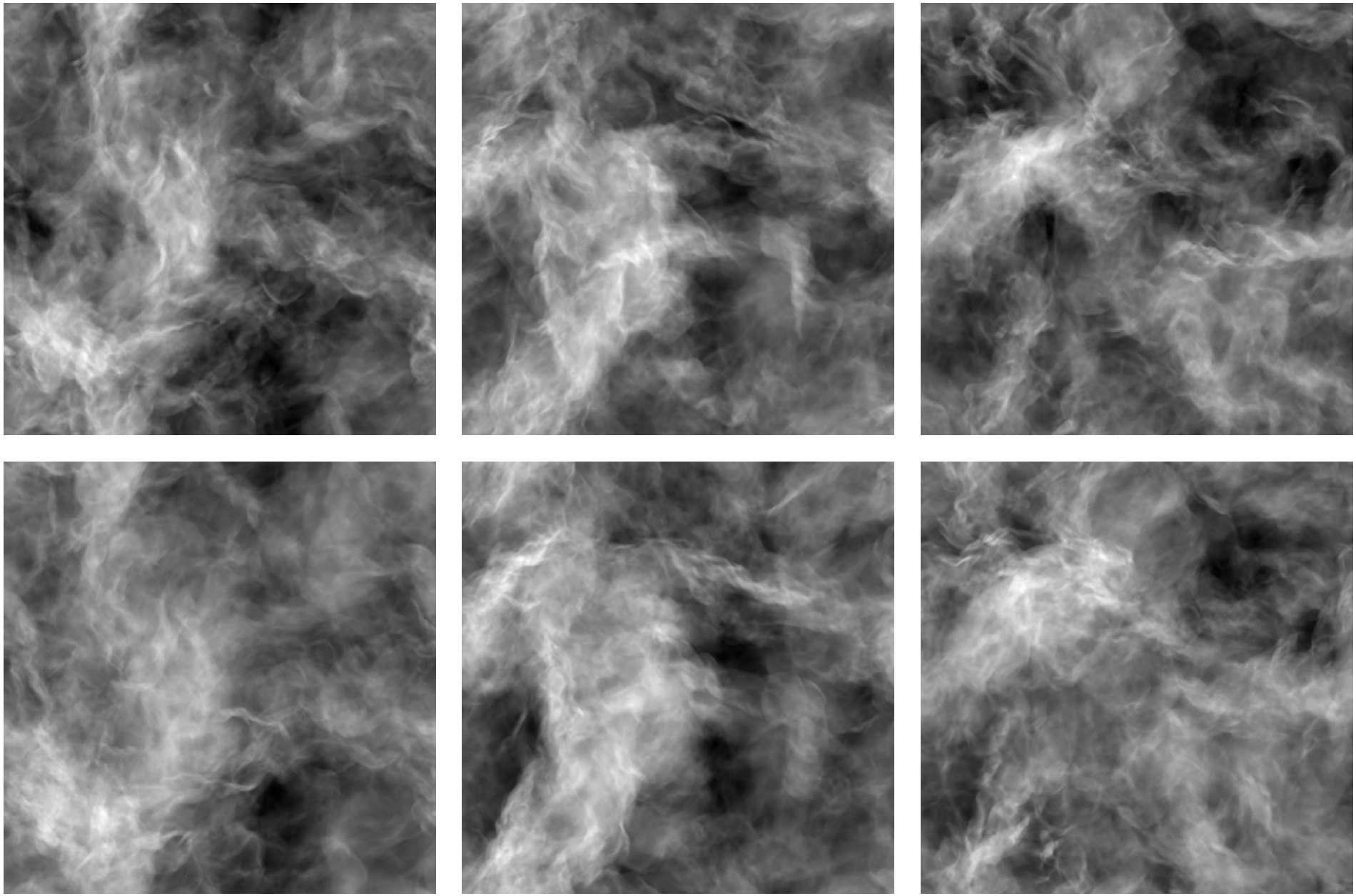
FLASH results – 512^3 polytropic eos column density



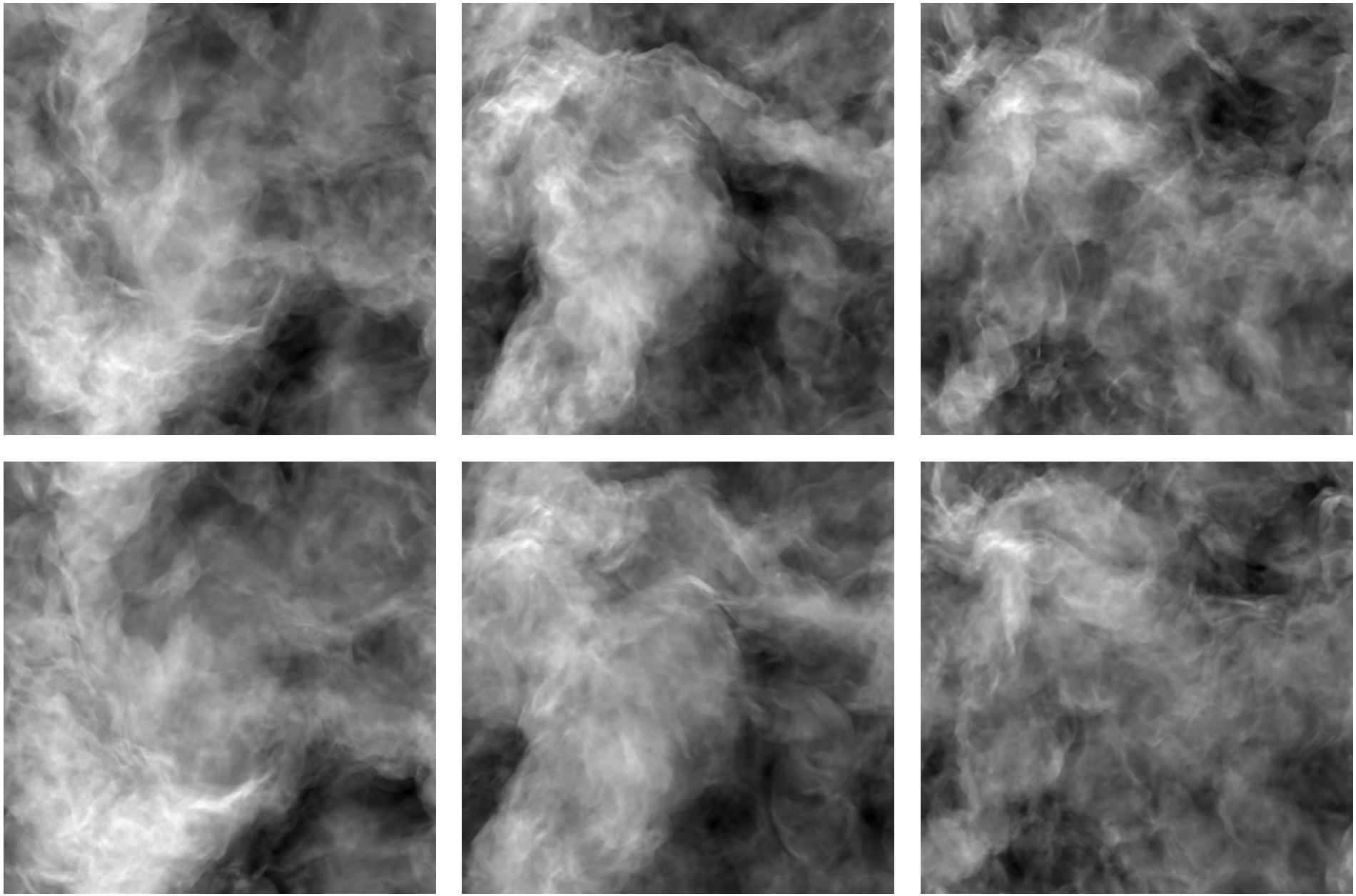
FLASH results – 512^3 polytropic eos column density



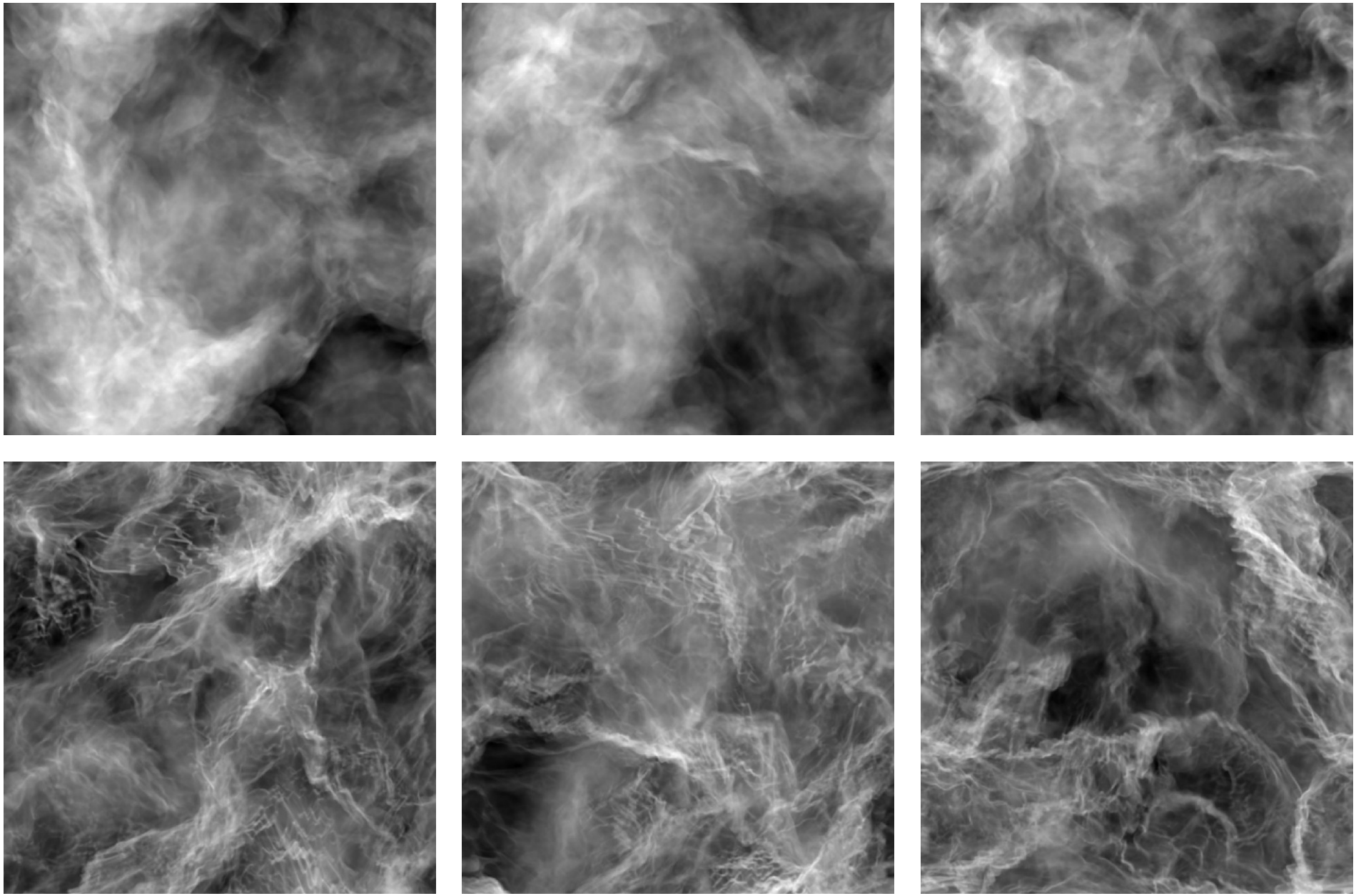
FLASH results – 512^3 polytropic eos column density



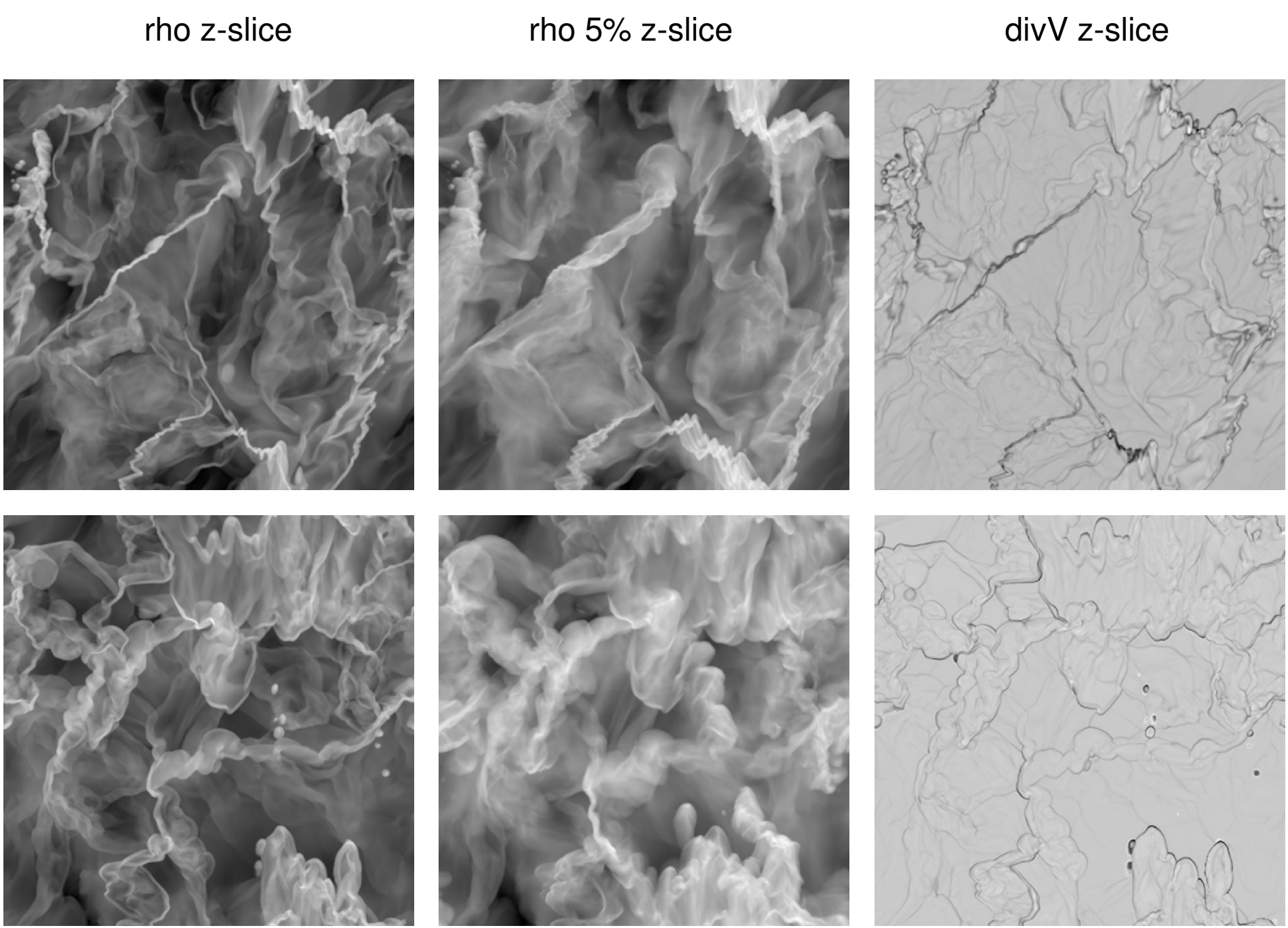
FLASH results – 512^3 polytropic eos column density



FLASH results – 512^3 polytropic eos column density



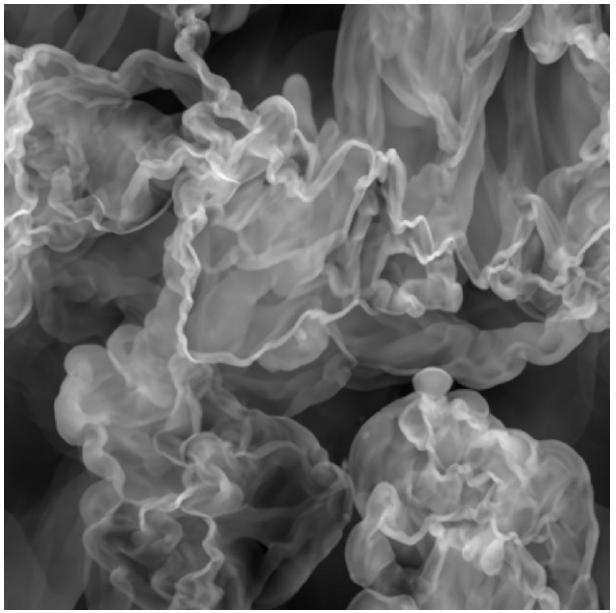
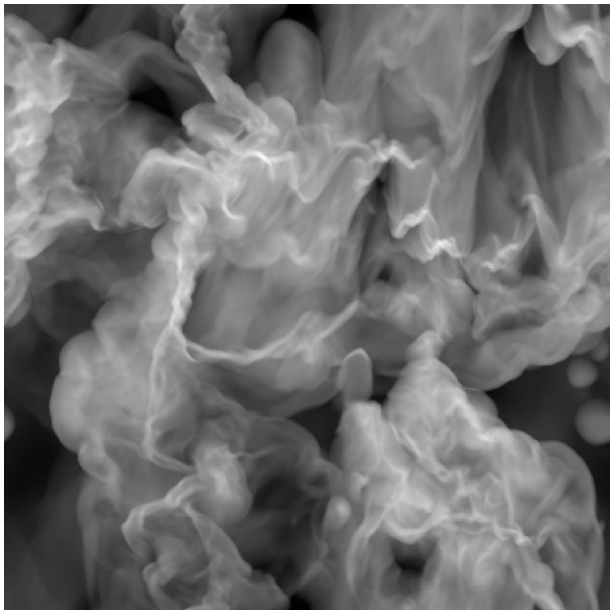
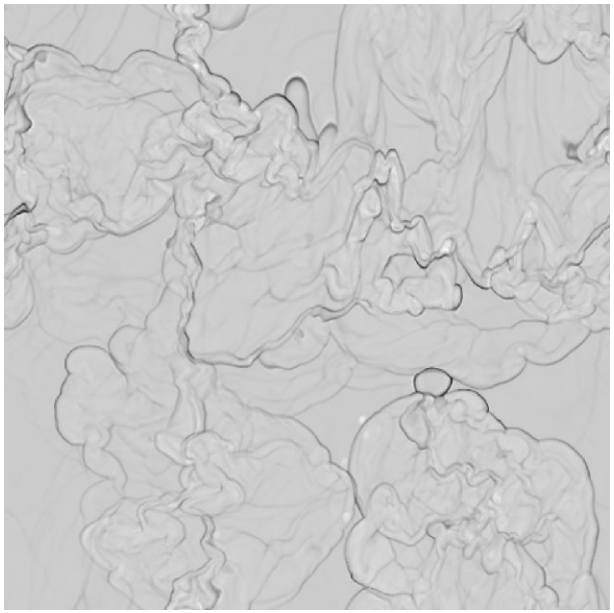
FLASH results – 512^3 polytropic eos rho z-slice, 5% z-slice, divV z-slice



FLASH results – 512^3 polytropic eos rho z-slice, 5% z-slice, divV z-slice

rho z-slice | rho 5% z-slice | divV z-slice

0.04

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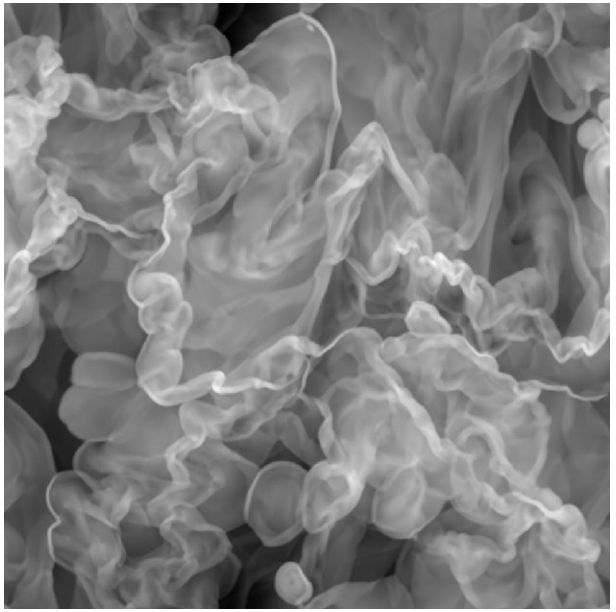
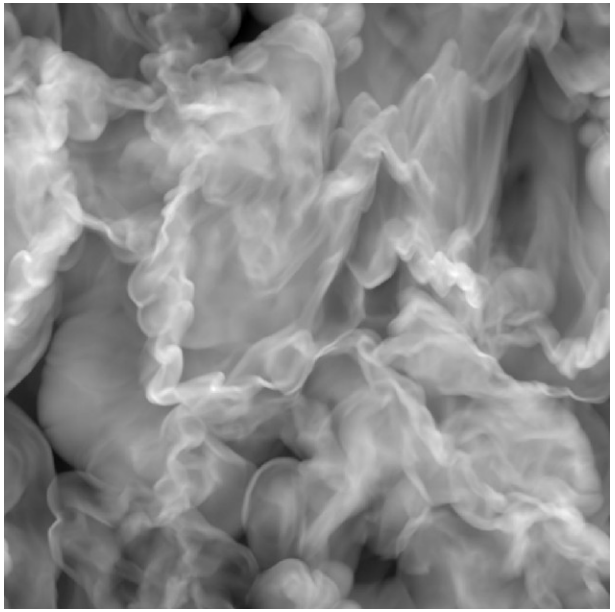
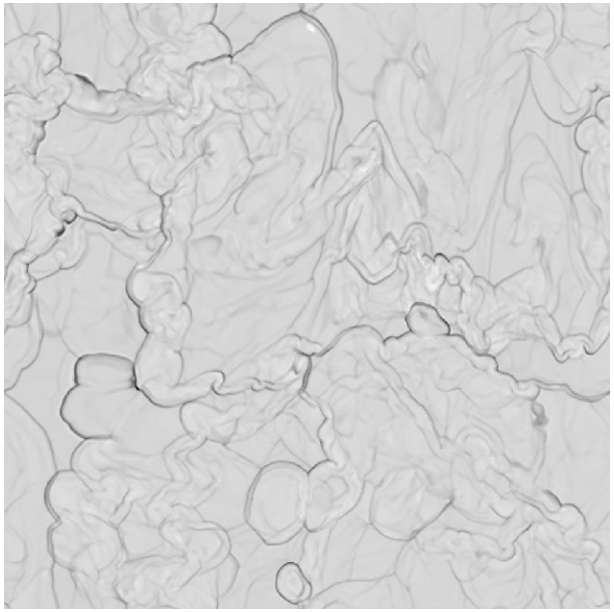
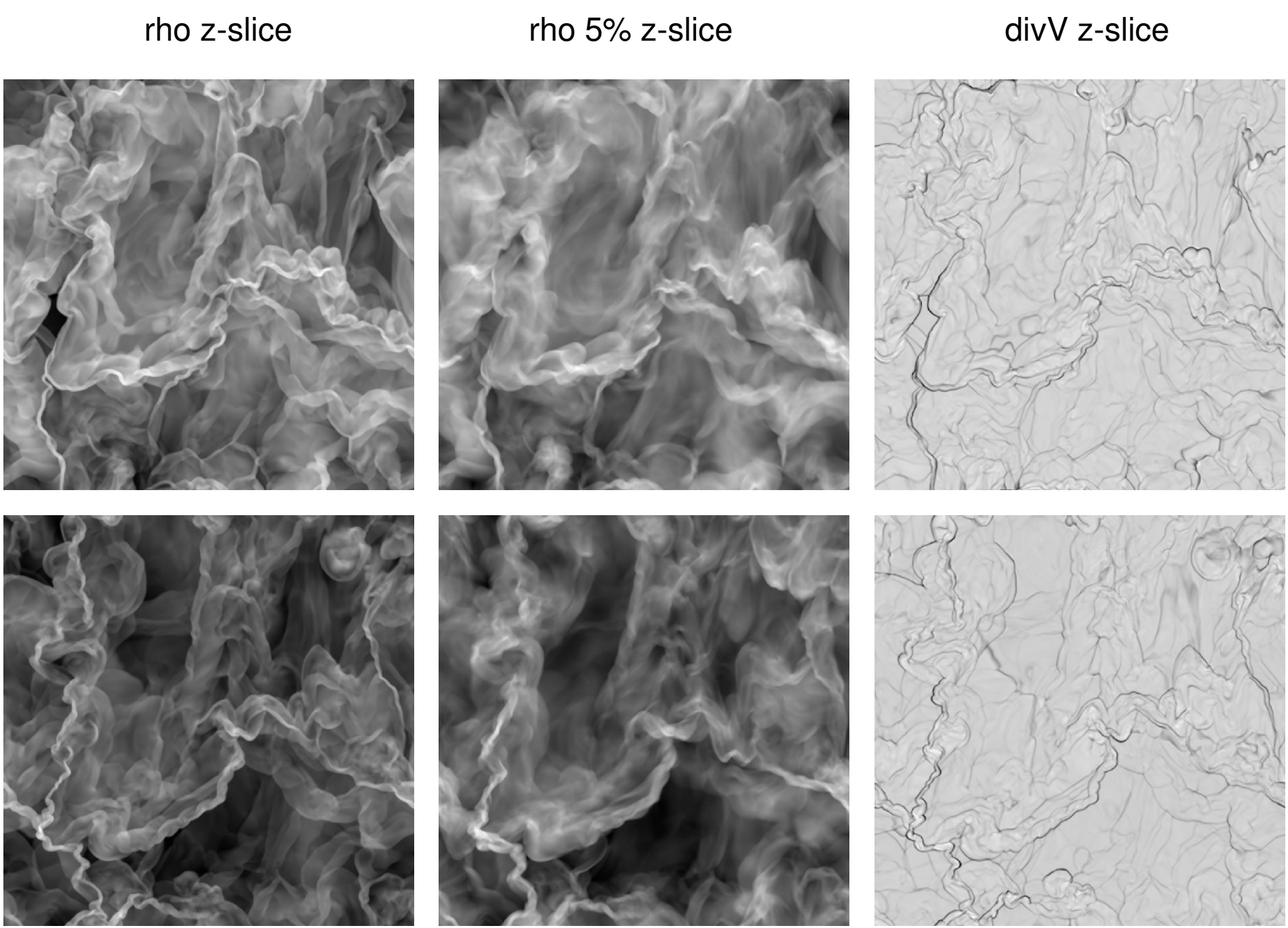
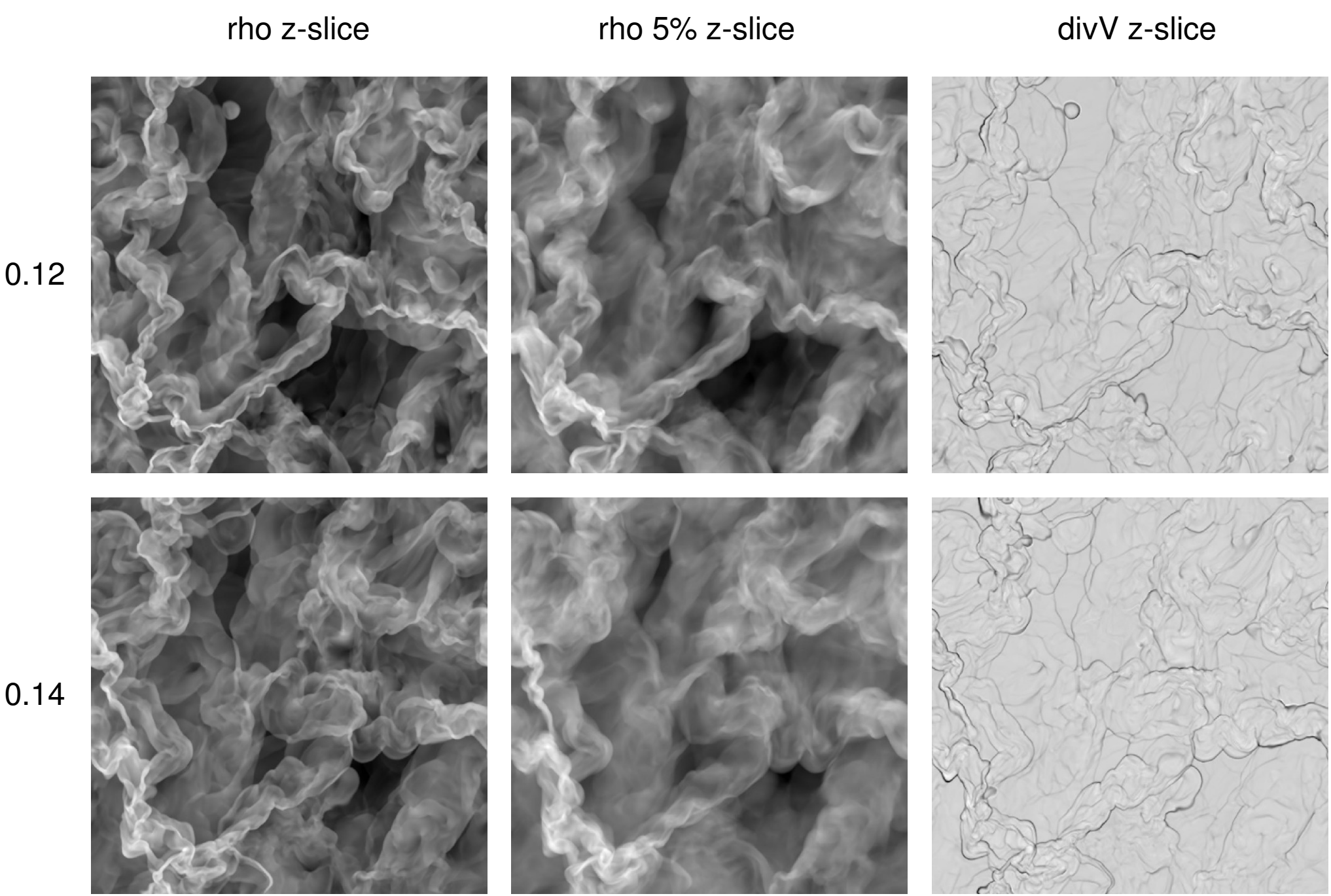




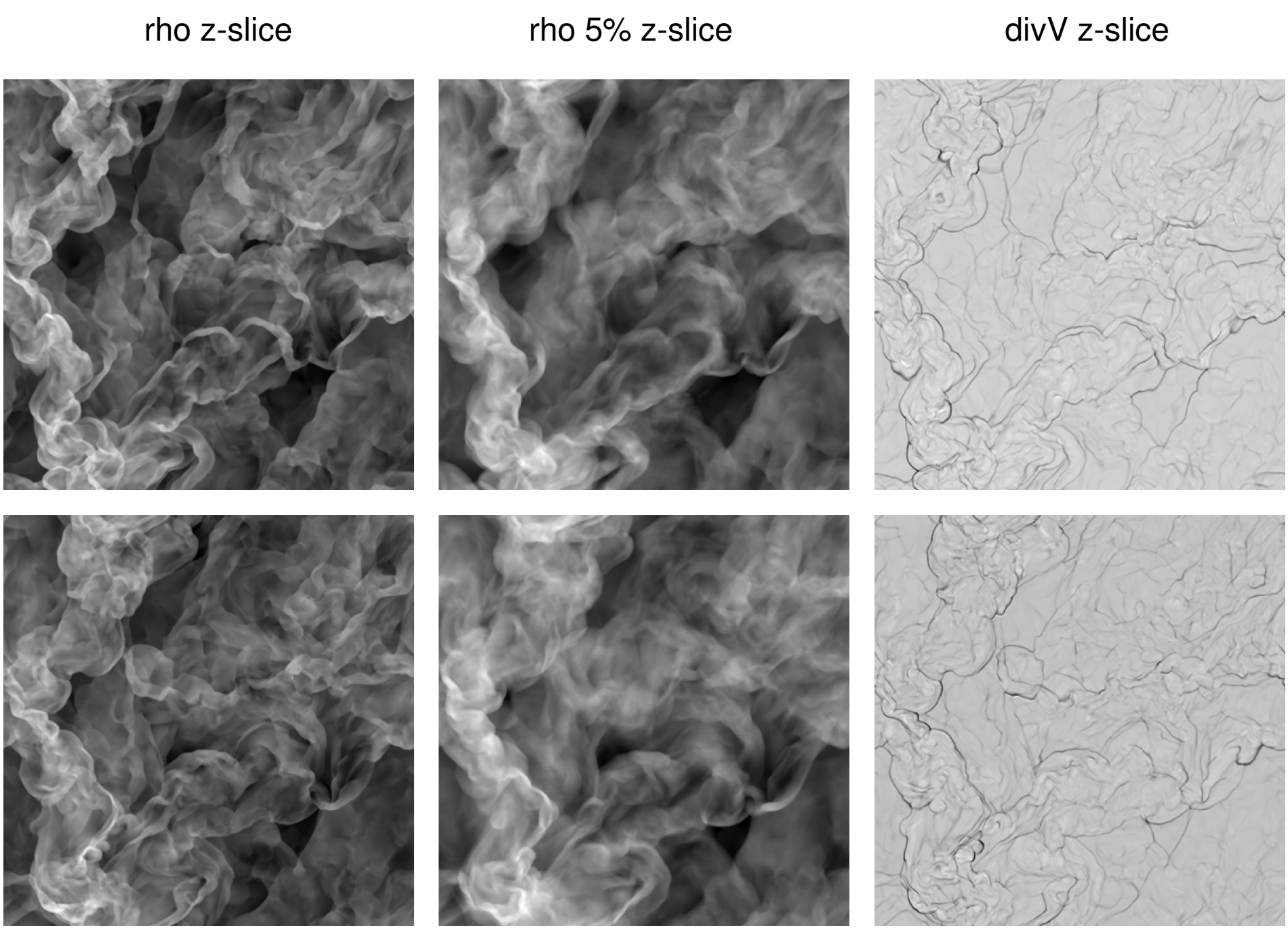
FLASH results – 512^3 polytropic eos rho z-slice, 5% z-slice, divV z-slice



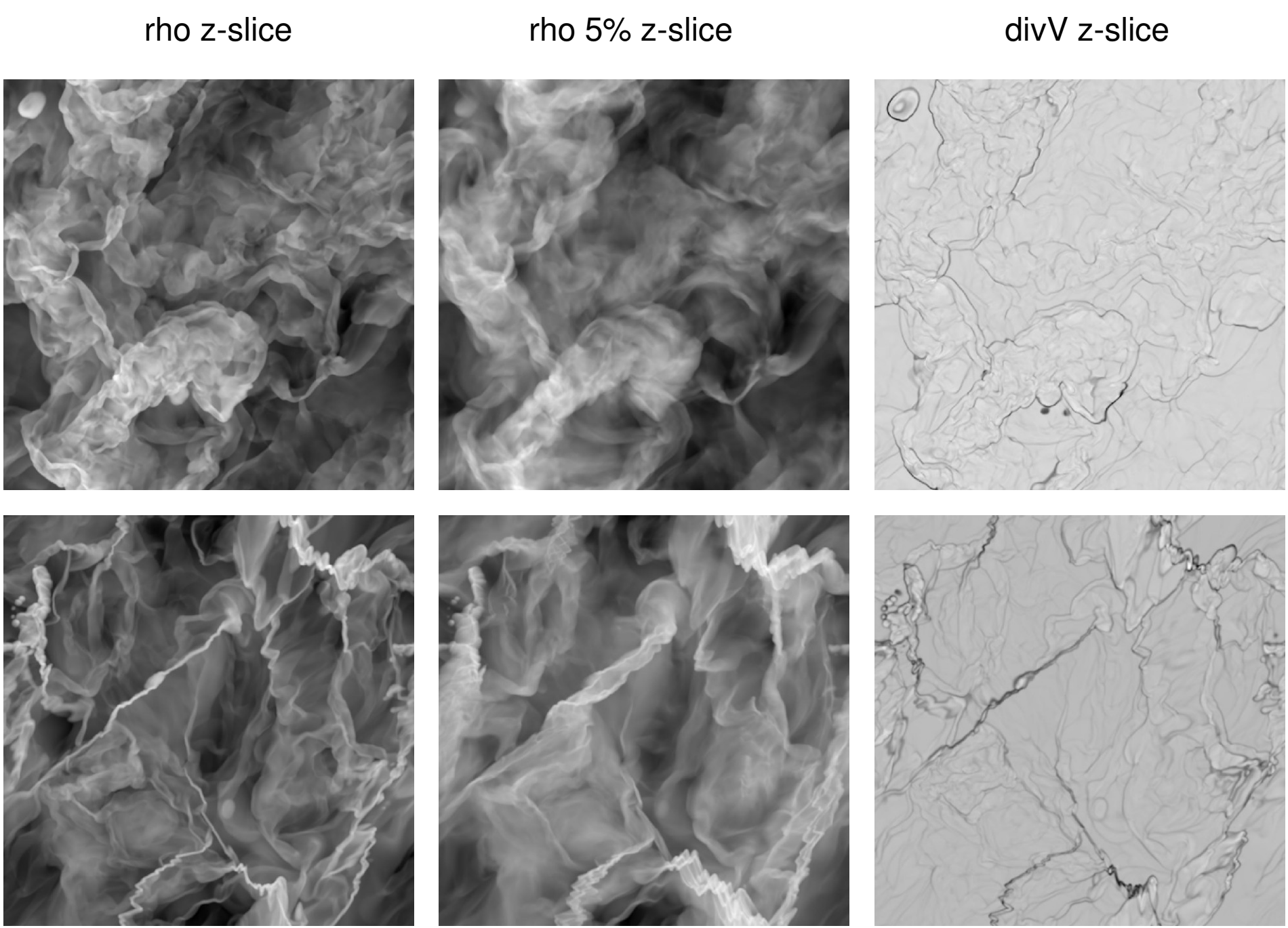
FLASH results – 512^3 polytropic eos rho z-slice, 5% z-slice, divV z-slice



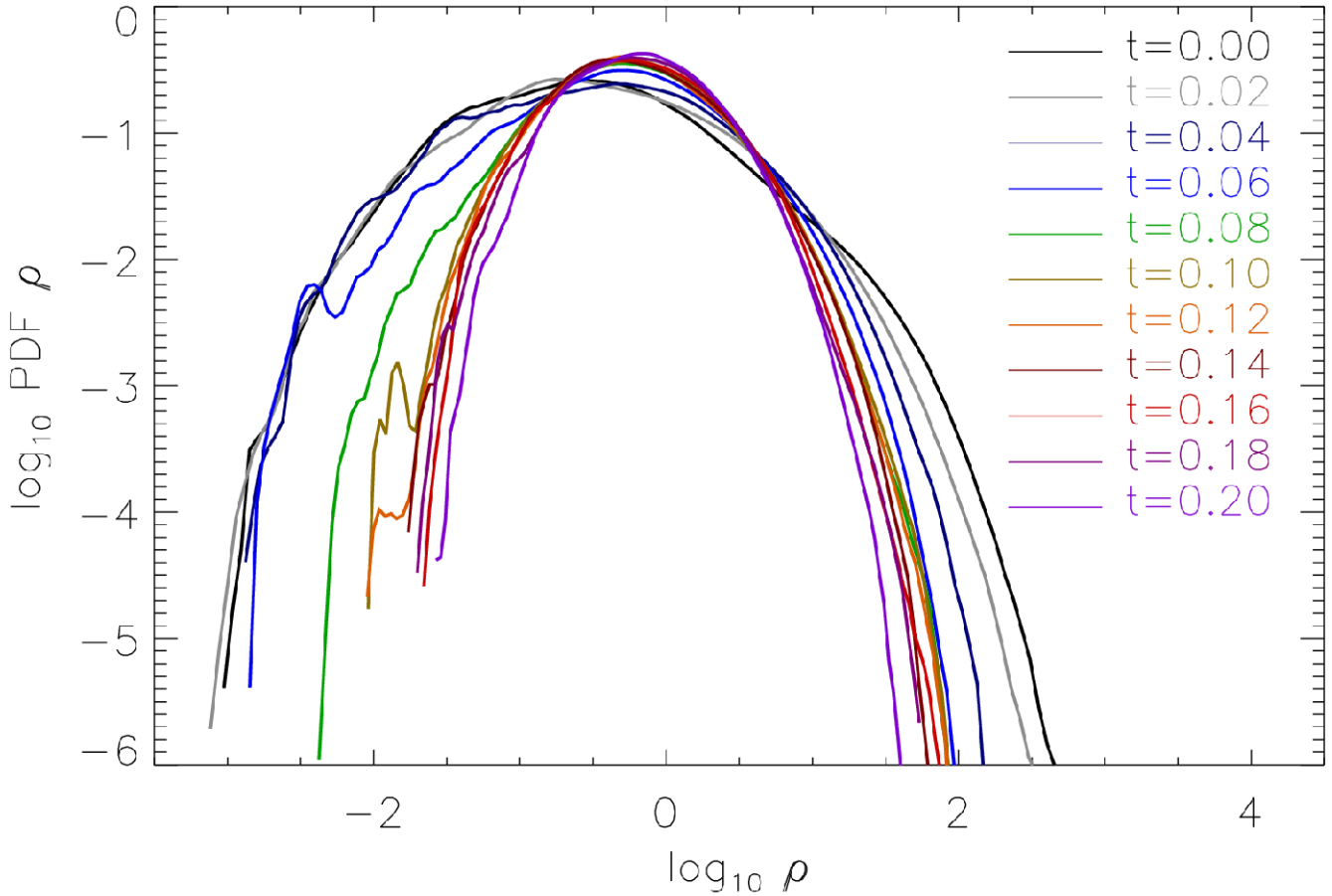
FLASH results – 512^3 polytropic eos rho z-slice, 5% z-slice, divV z-slice



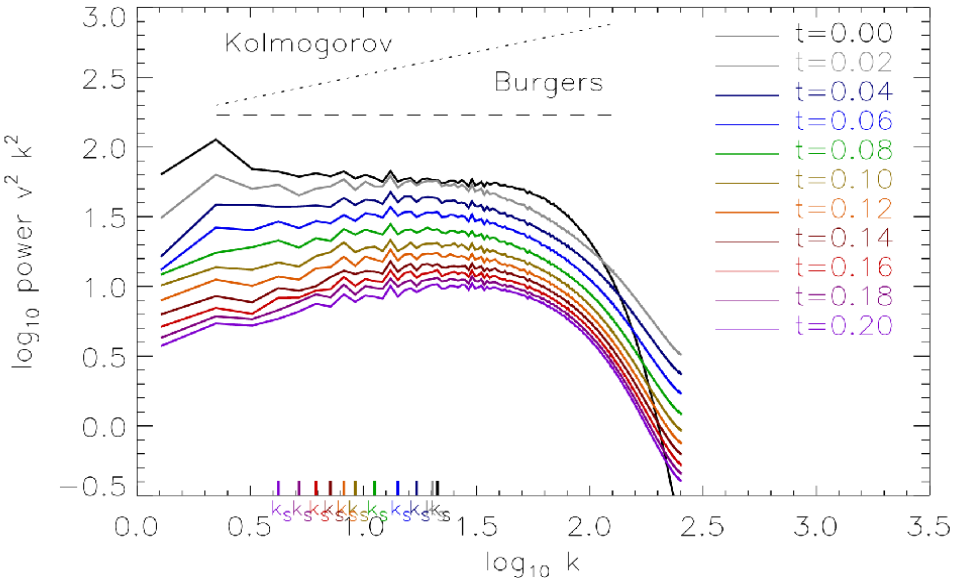
FLASH results – 512^3 polytropic eos rho z-slice, 5% z-slice, divV z-slice

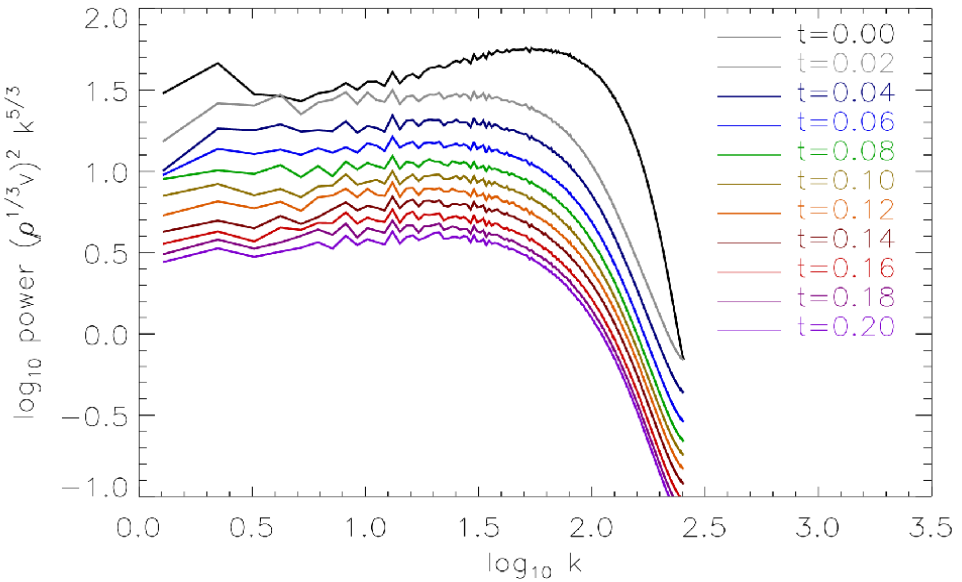


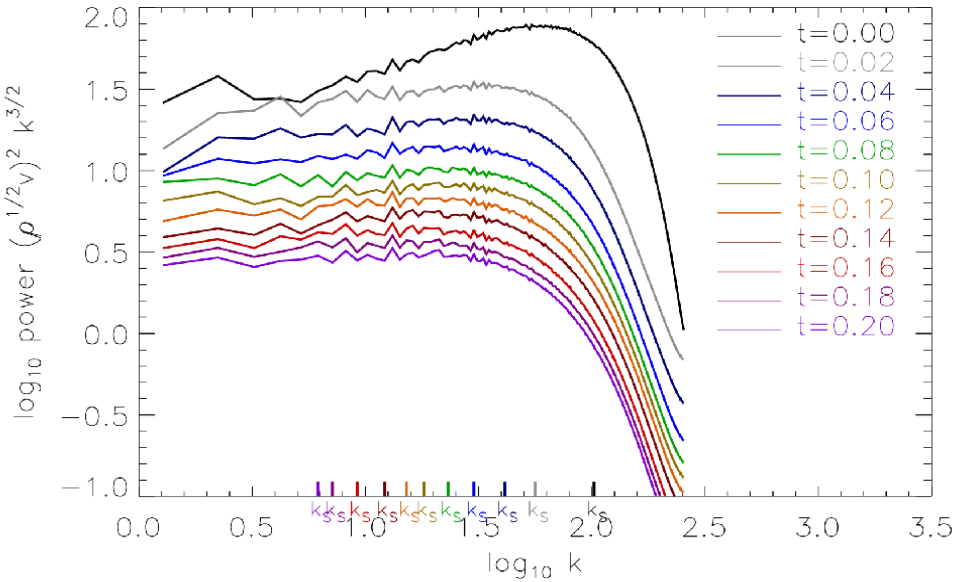
FLASH results – 512^3 polytropic eos density PDF

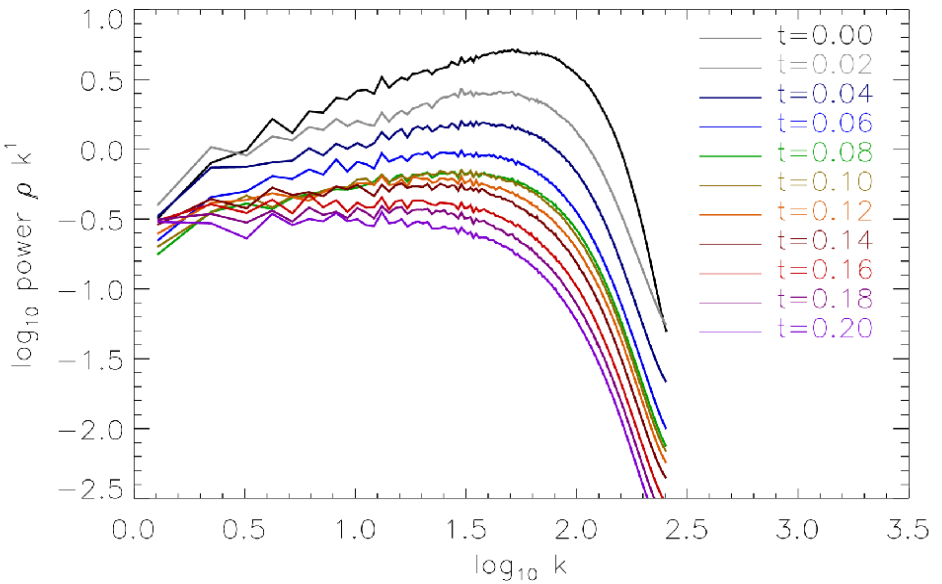


FLASH results – 512^3 polytropic eos power spectra



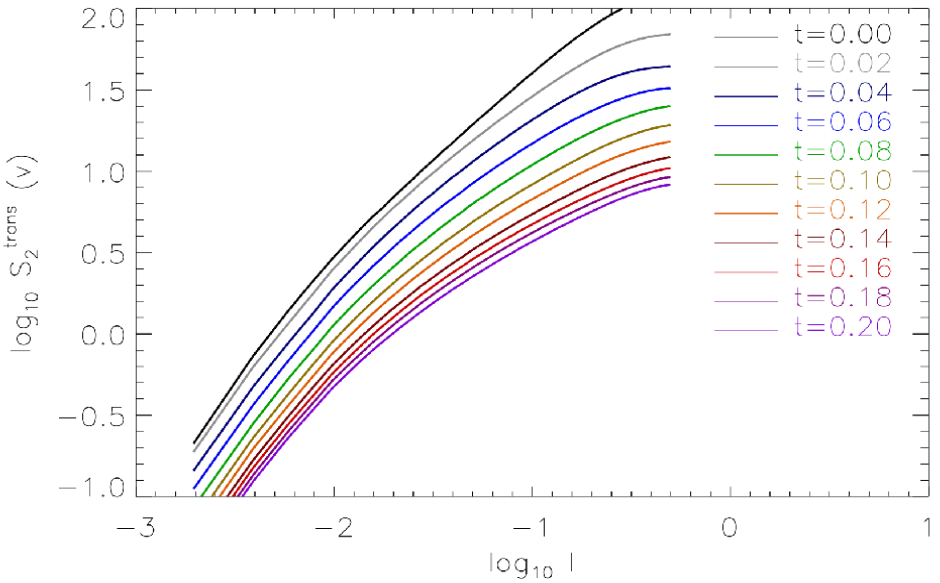




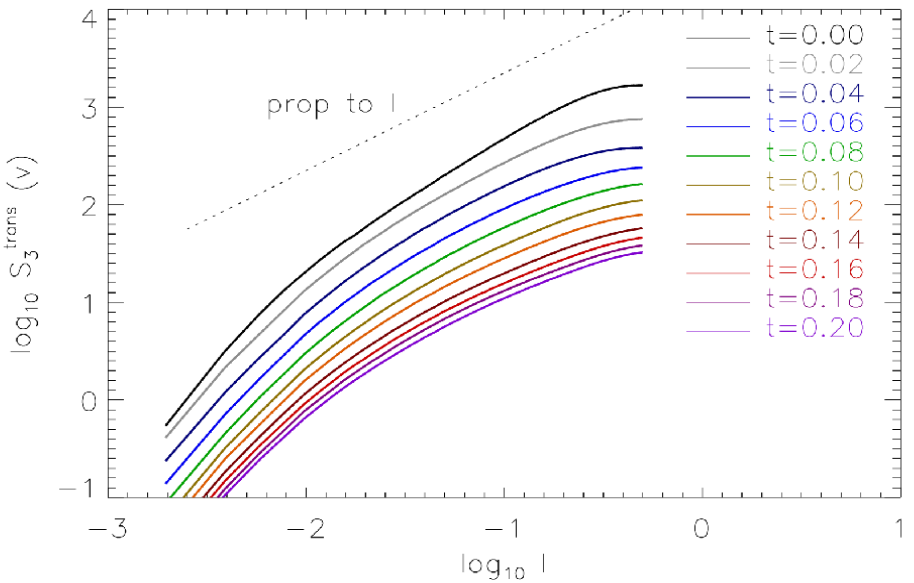


FLASH results – 512^3 polytropic eos structure functions

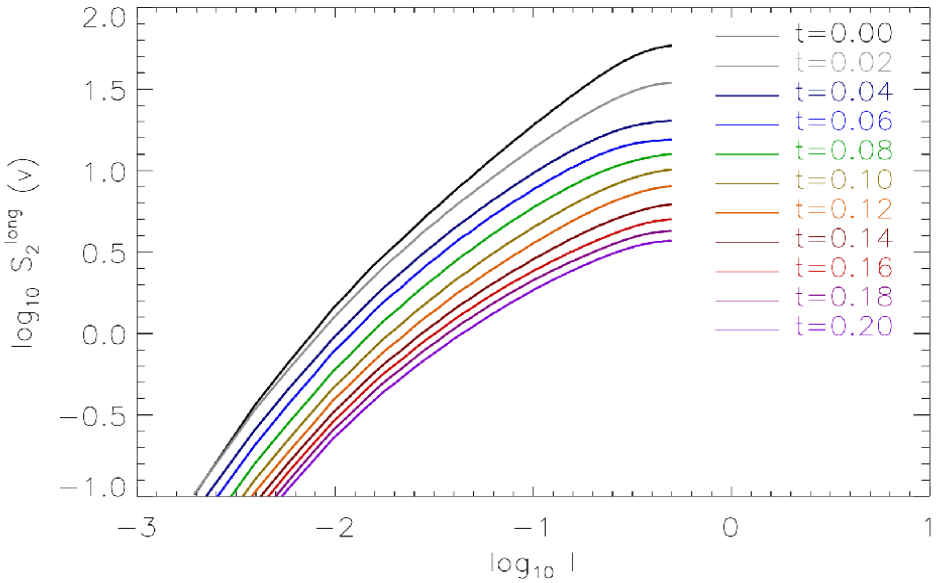
2nd order transversal



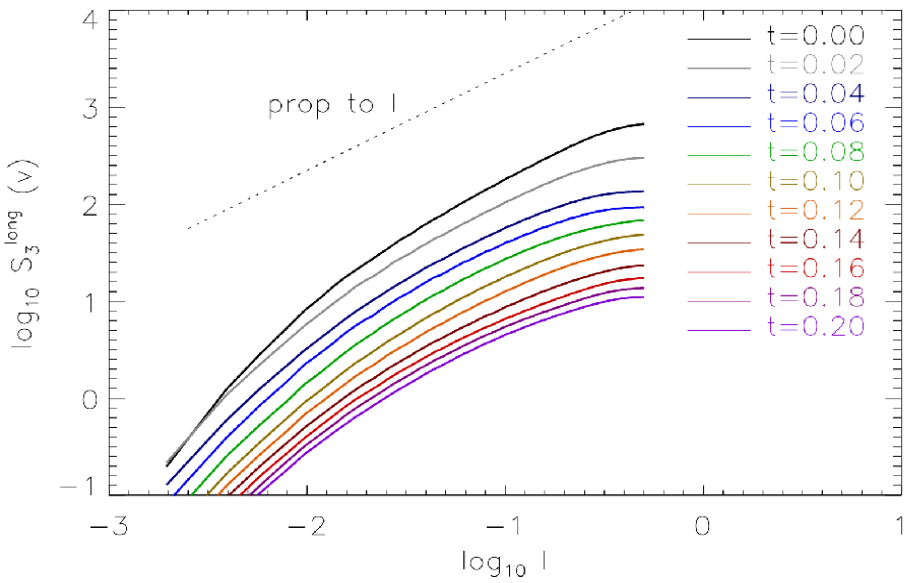
3rd order transversal



2nd order longitudinal

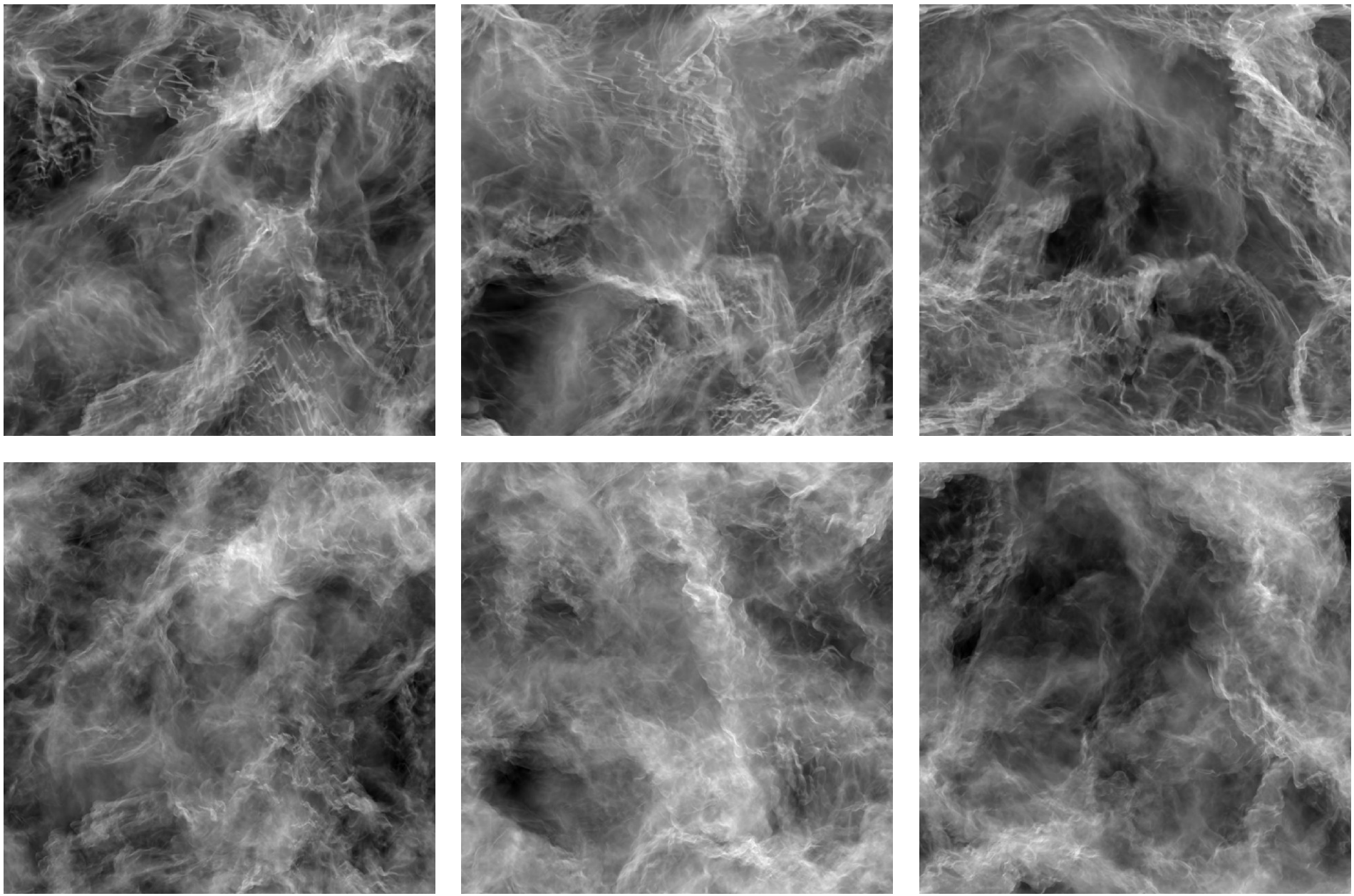


3rd order longitudinal

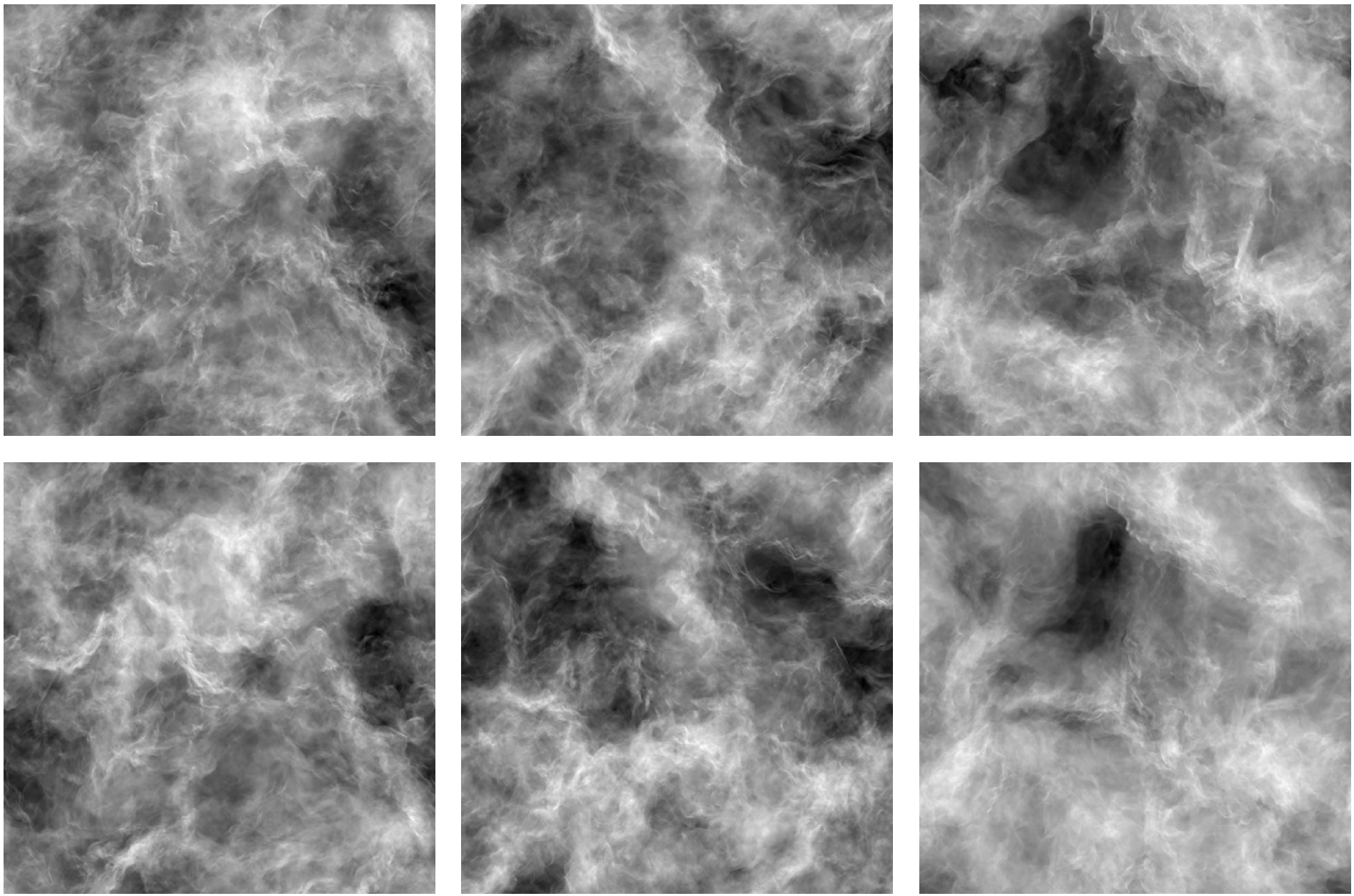


HD 1024^3
with proper
isothermal equation of state

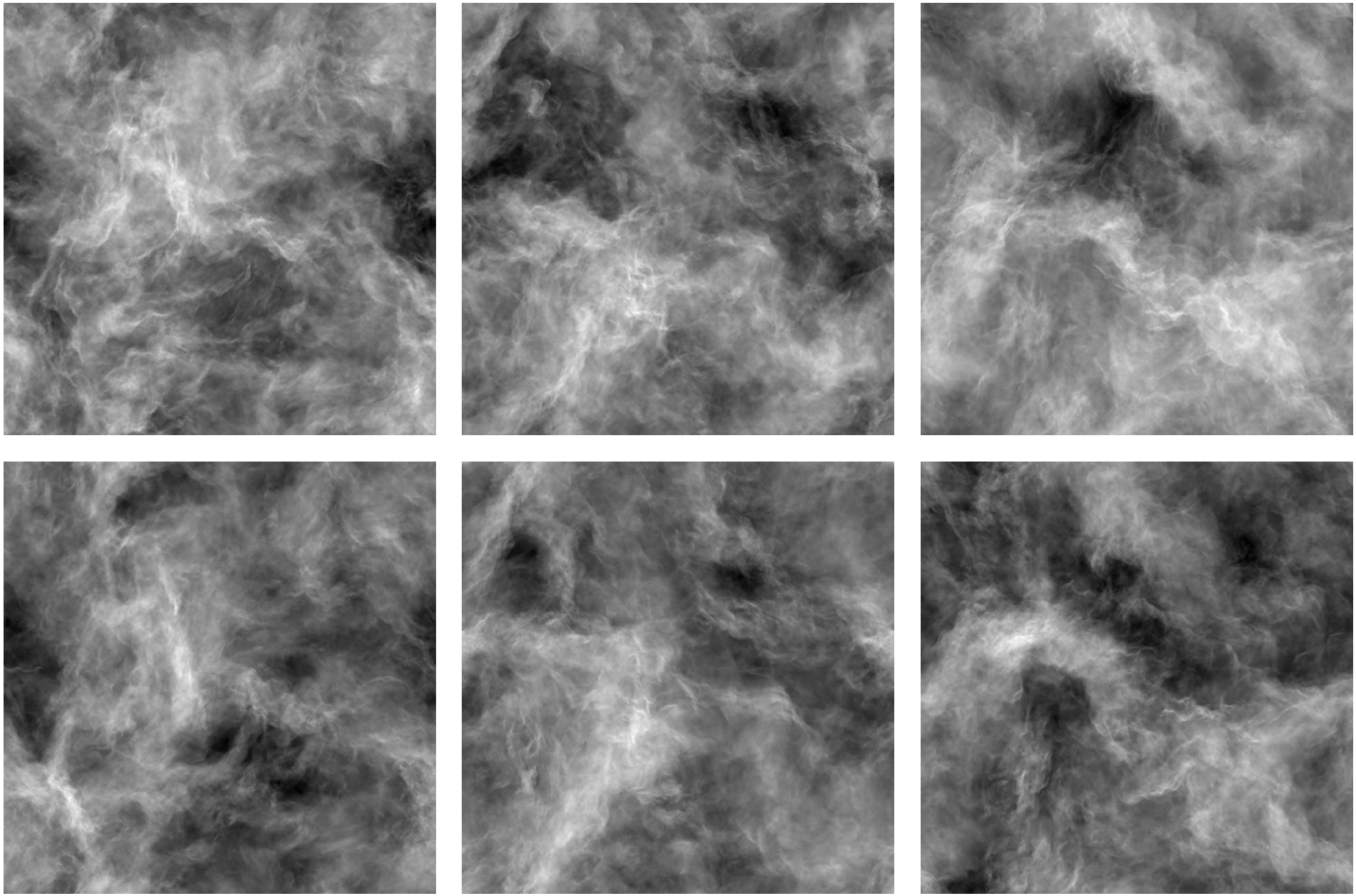
FLASH results – 1024^3 polytropic eos column density



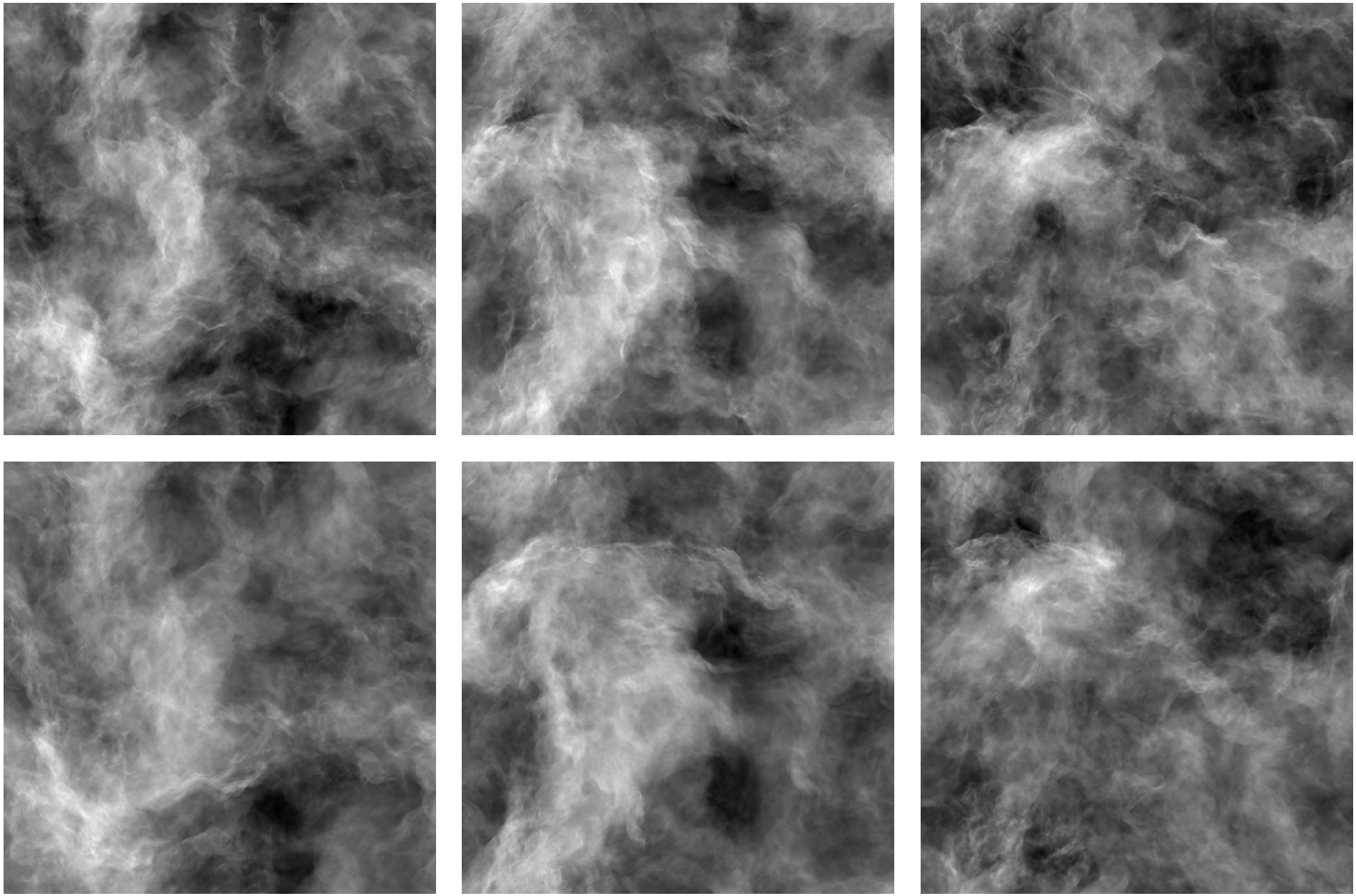
FLASH results – 1024^3 polytropic eos column density



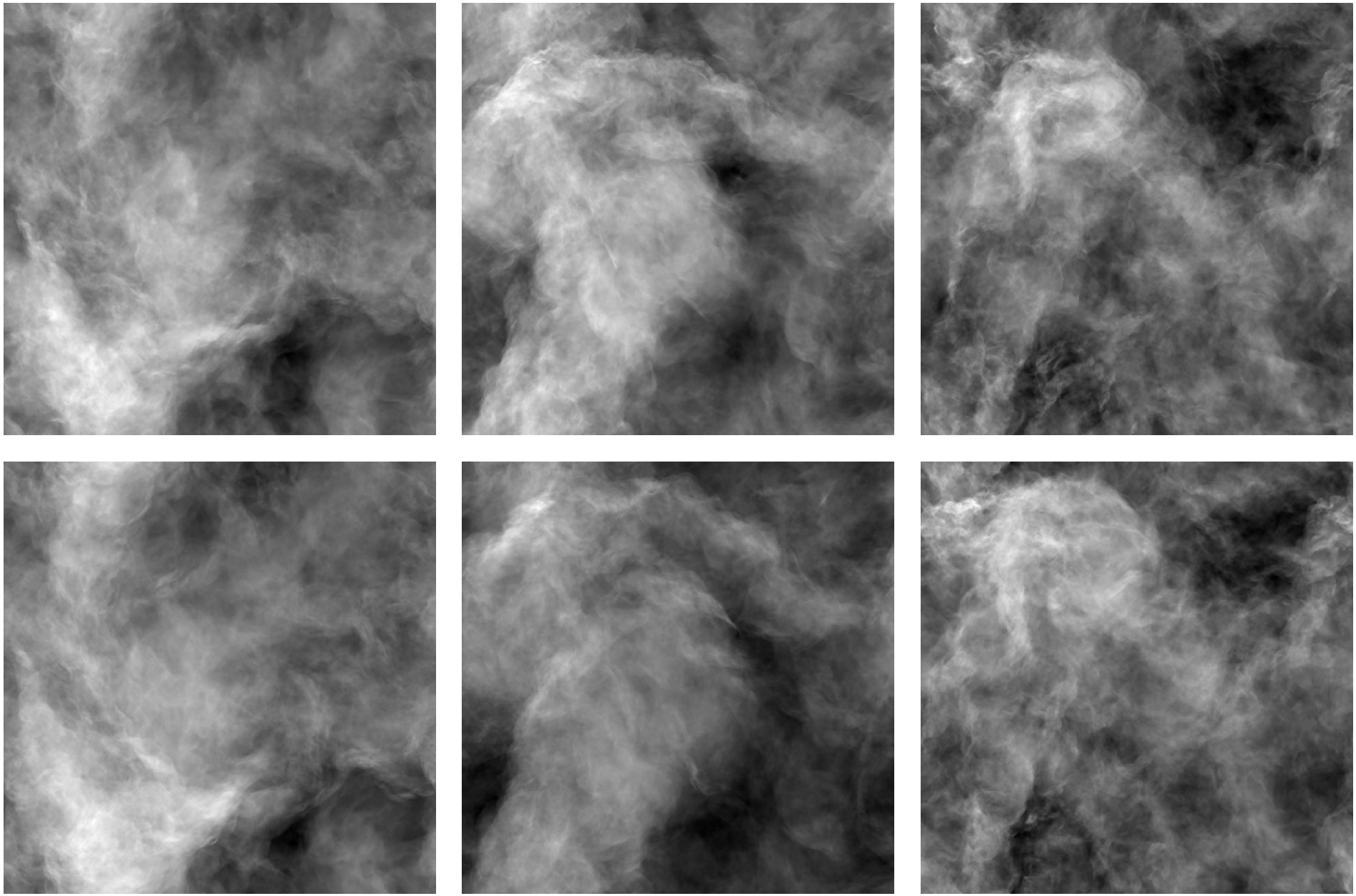
FLASH results – 1024^3 polytropic eos column density



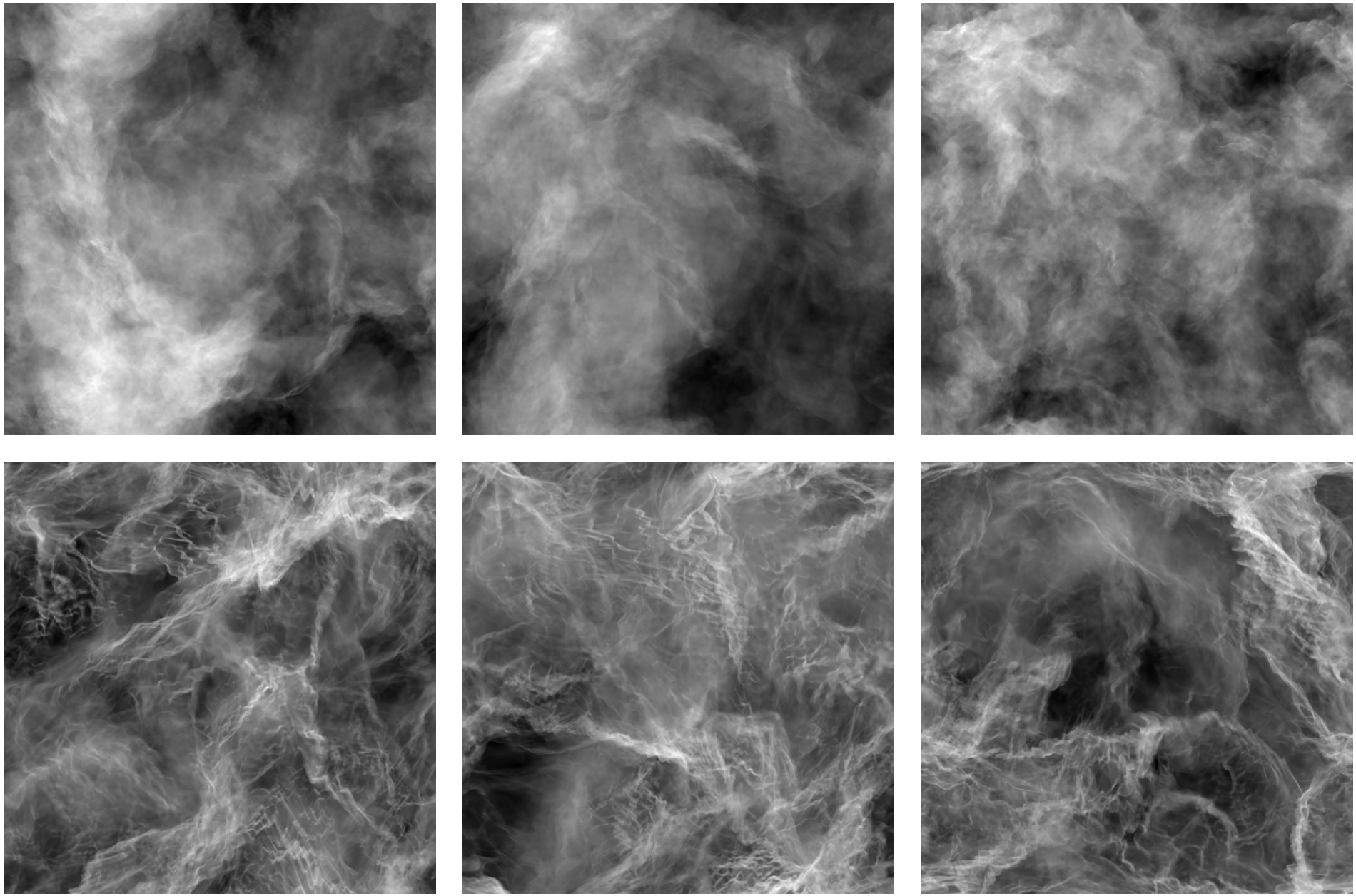
FLASH results – 1024^3 polytropic eos column density



FLASH results – 1024^3 polytropic eos column density



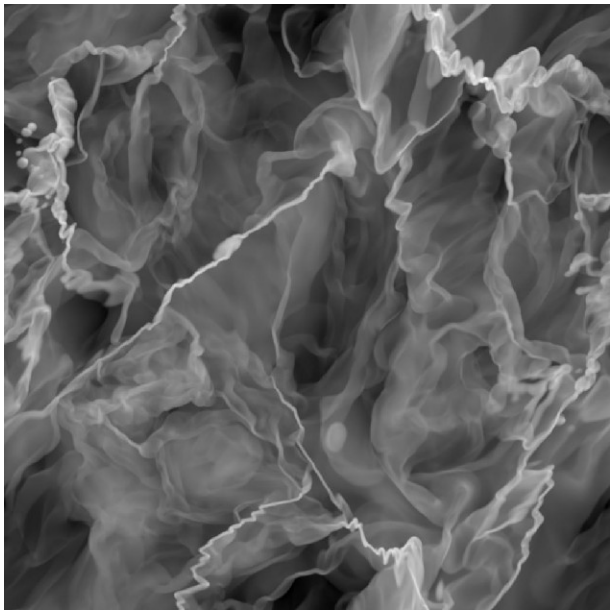
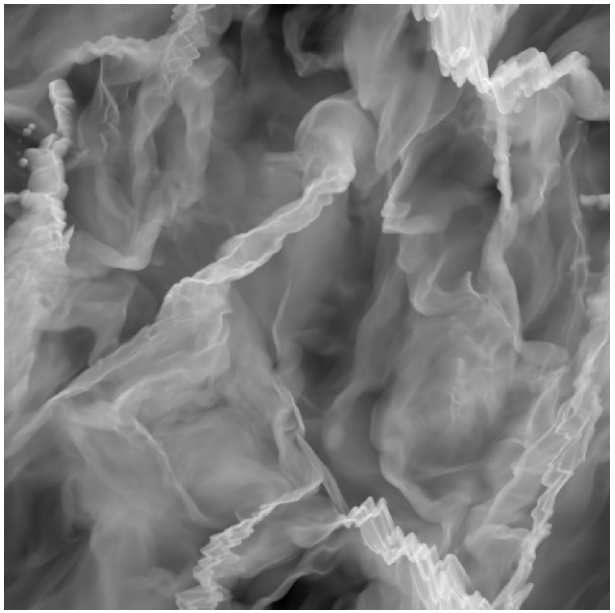
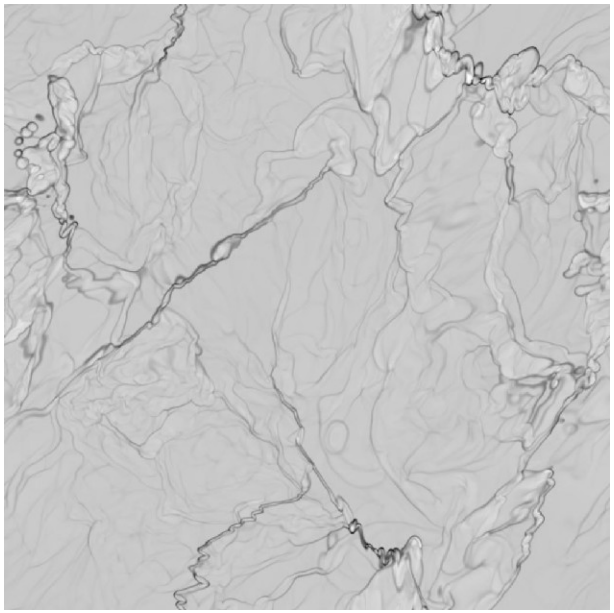
FLASH results – 1024^3 polytropic eos column density



FLASH results – 1024^3 polytropic eos rho z-slice, 5% z-slice, divV z-slice

rho z-slice | rho 5% z-slice | divV z-slice

0.00

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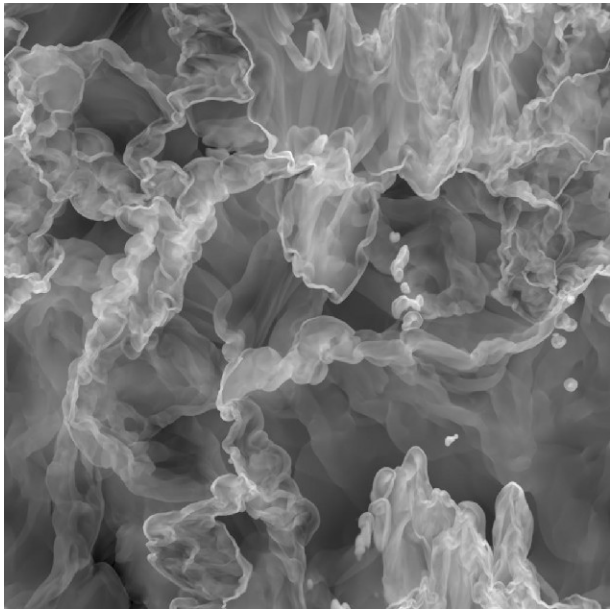
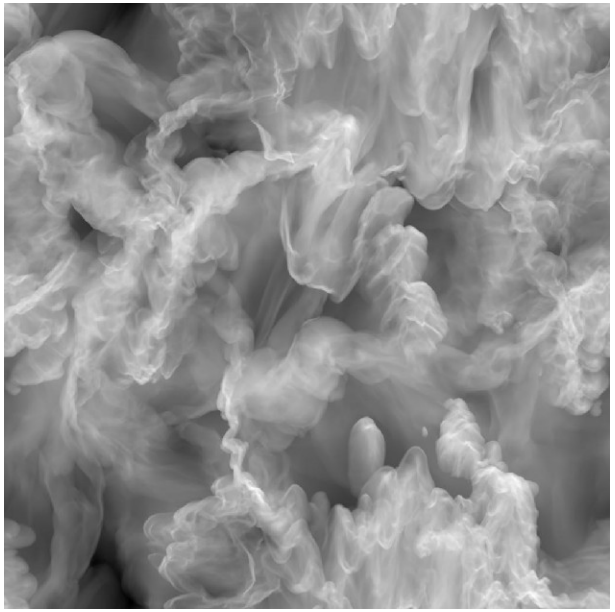
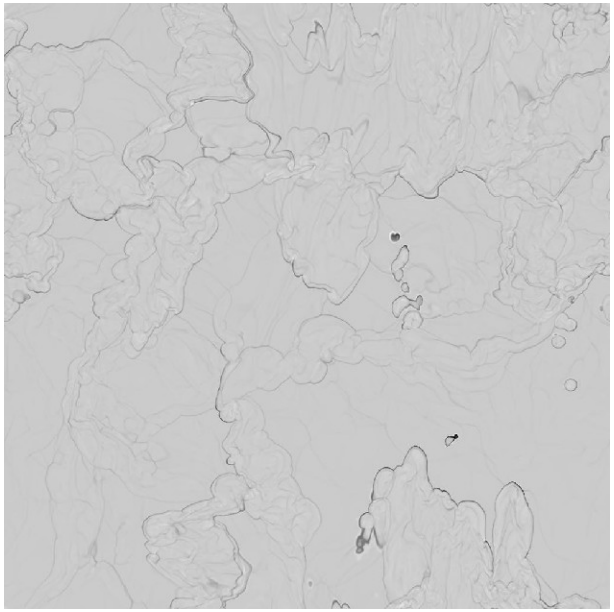
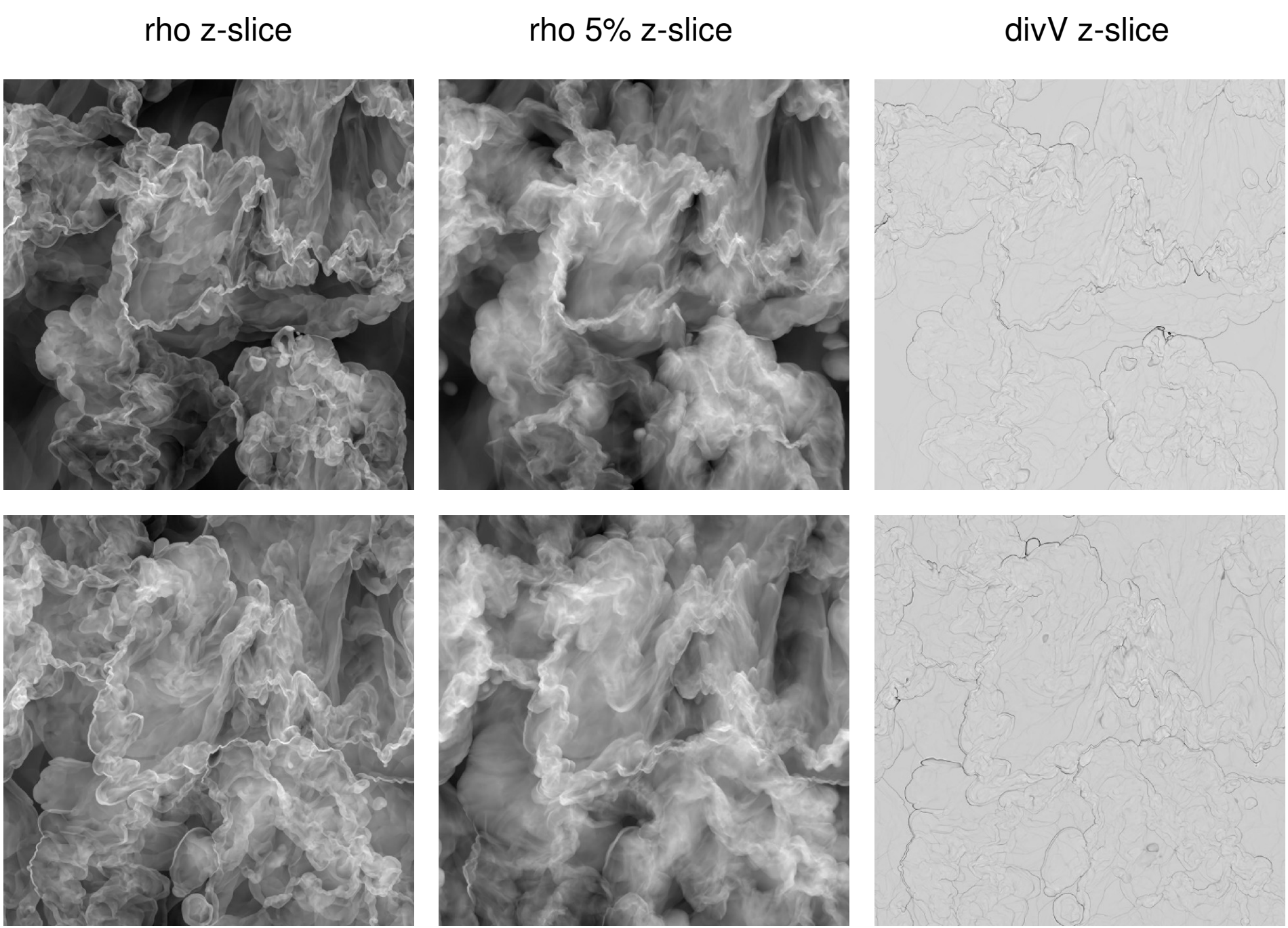
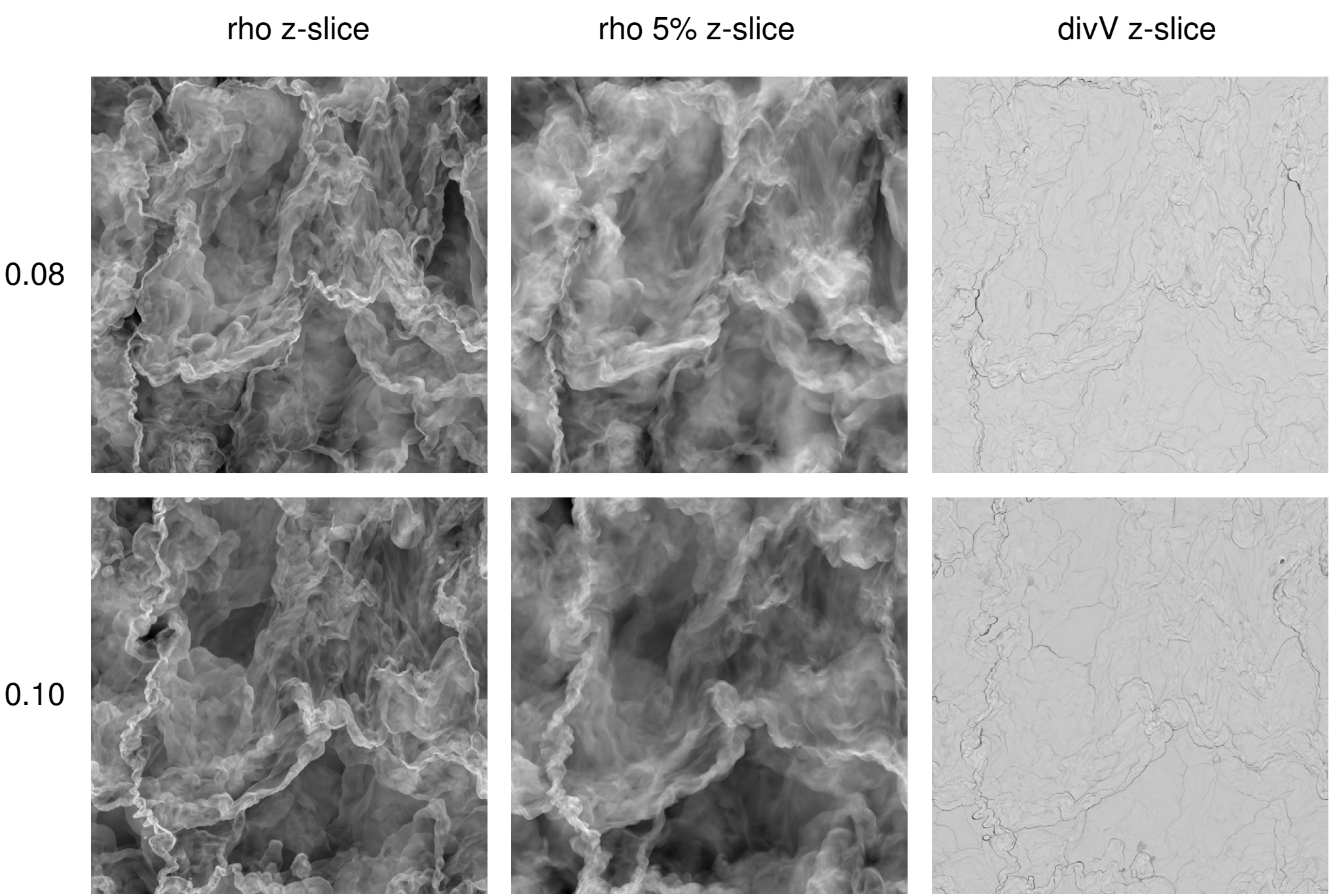




FLASH results – 1024^3 polytropic eos rho z-slice, 5% z-slice, divV z-slice



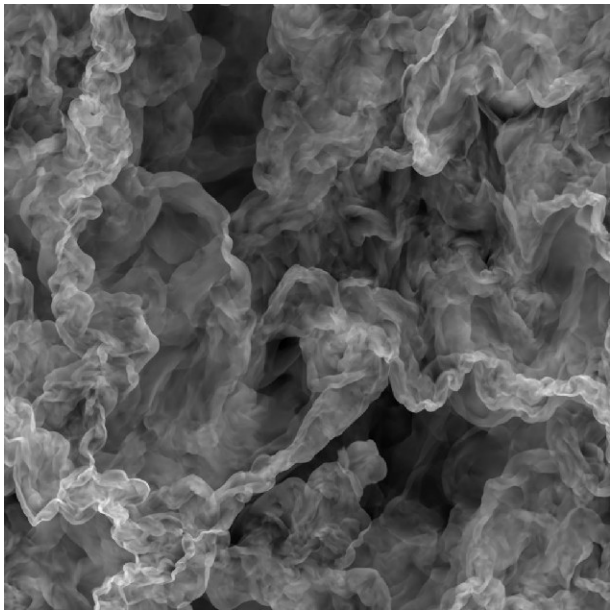
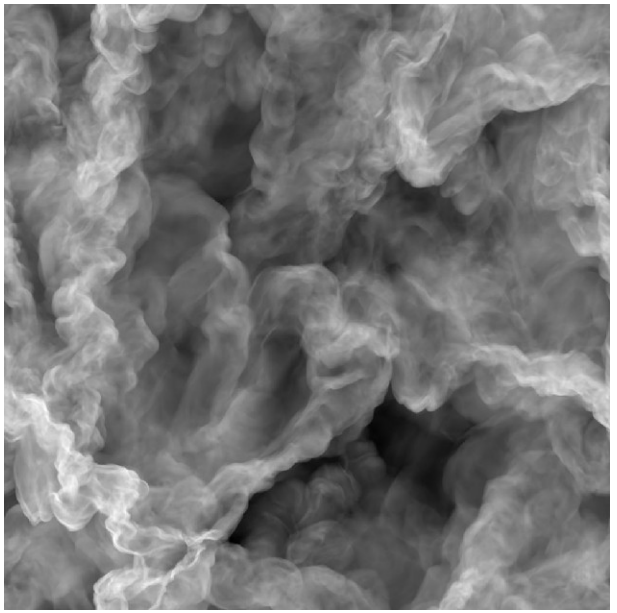
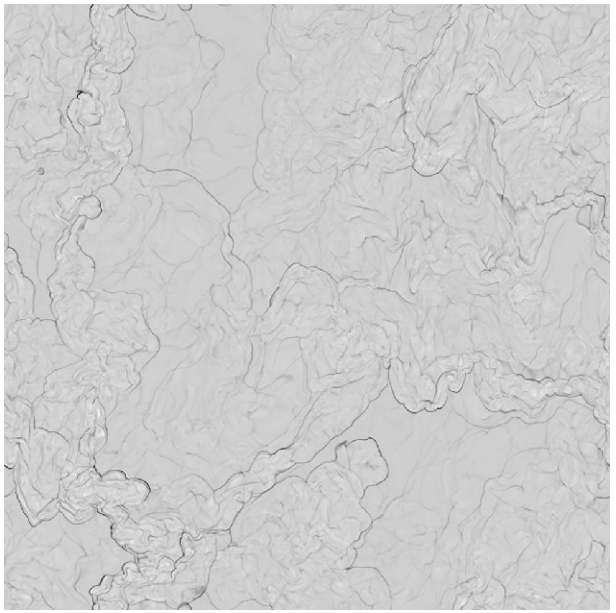
FLASH results – 1024^3 polytropic eos rho z-slice, 5% z-slice, divV z-slice



FLASH results – 1024^3 polytropic eos rho z-slice, 5% z-slice, divV z-slice

rho z-slice | rho 5% z-slice | divV z-slice

0.12

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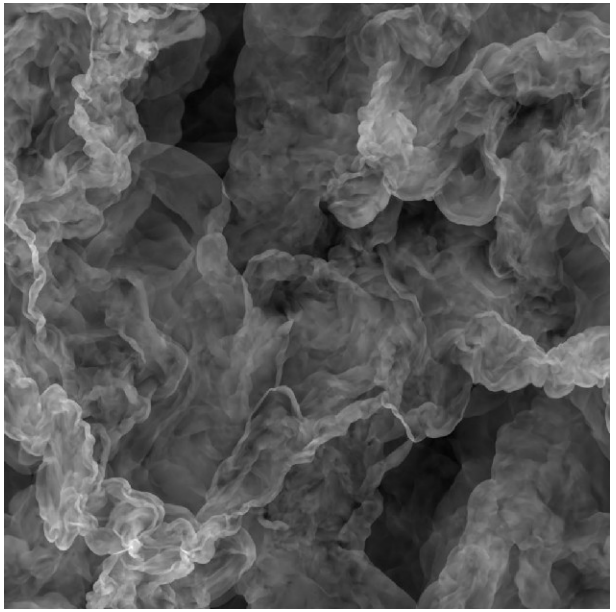
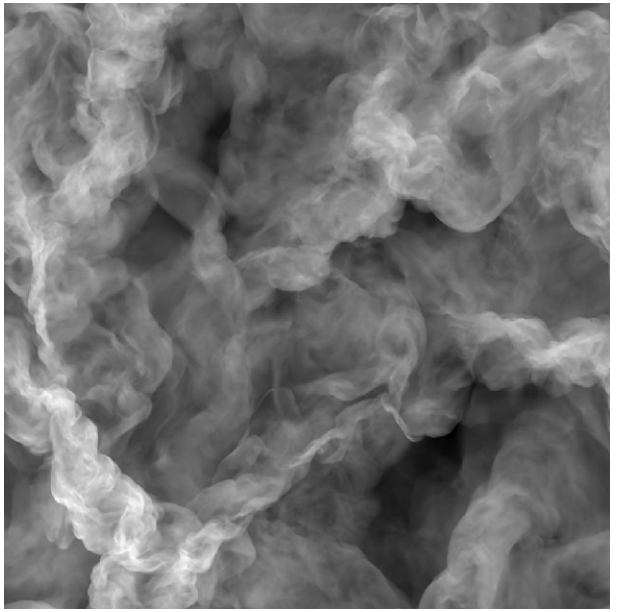
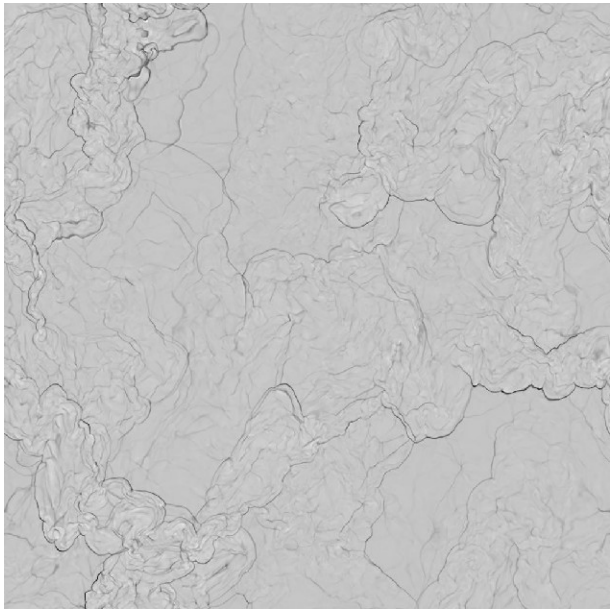
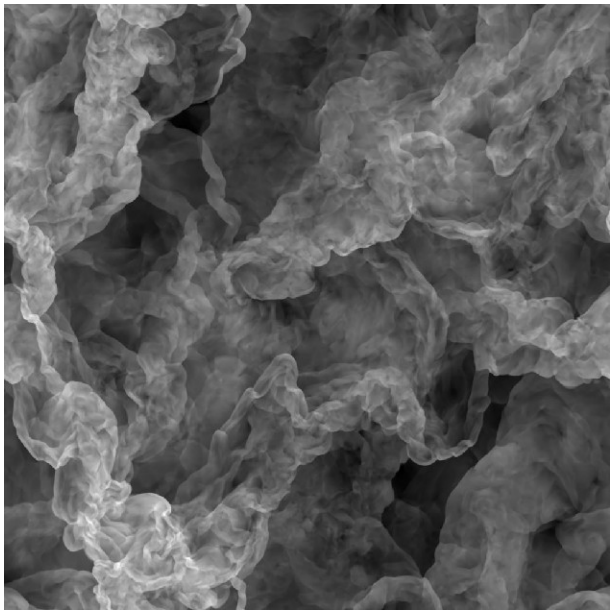
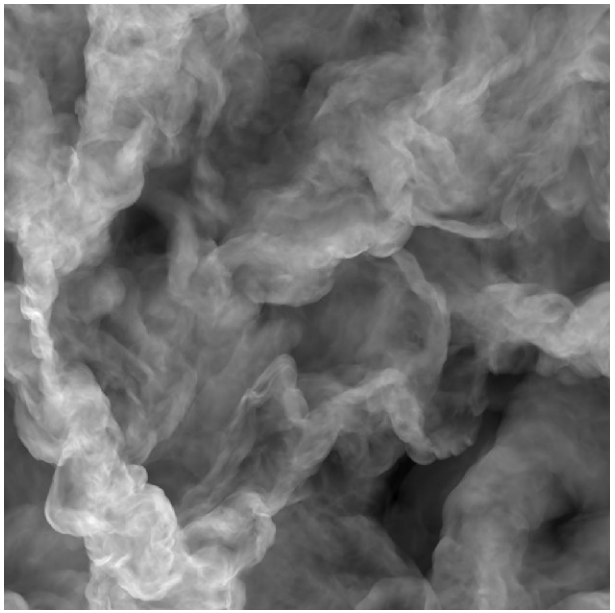
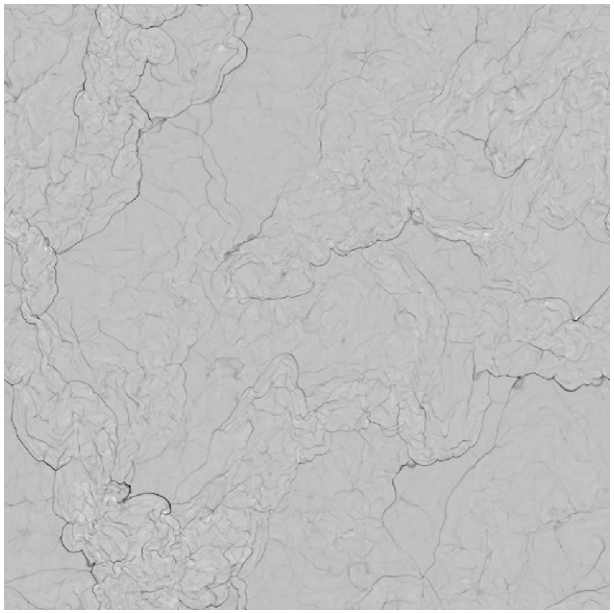




FLASH results – 1024^3 polytropic eos rho z-slice, 5% z-slice, divV z-slice

rho z-slice | rho 5% z-slice | divV z-slice

0.16

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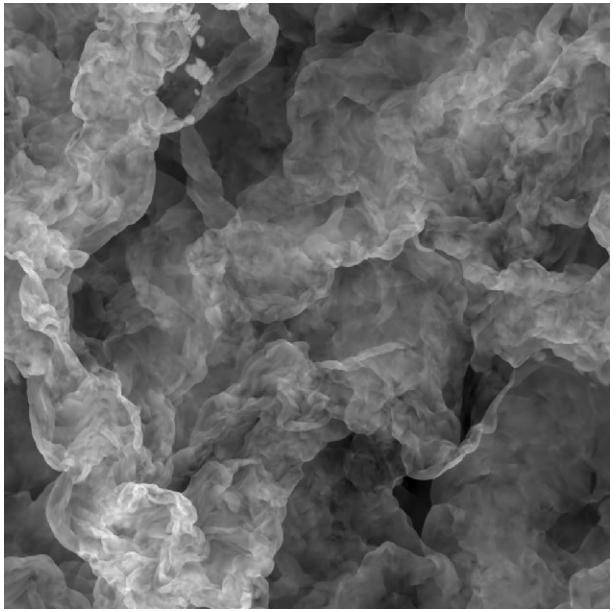
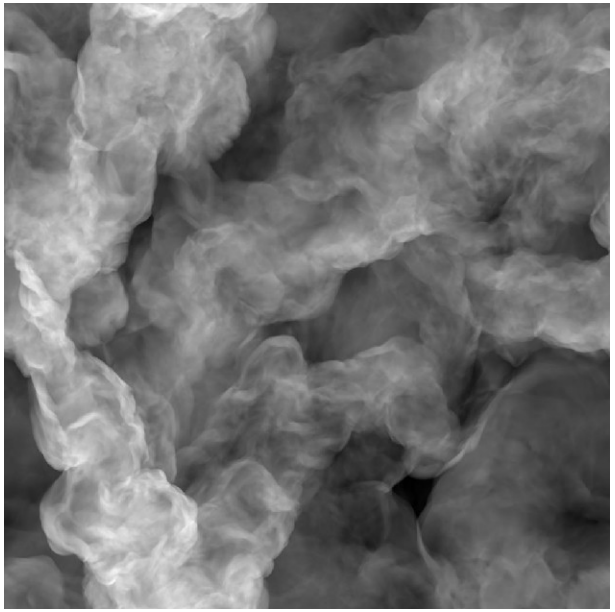
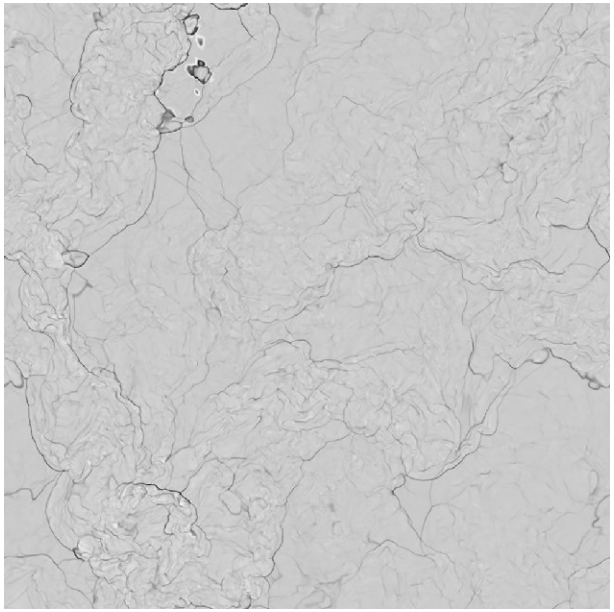
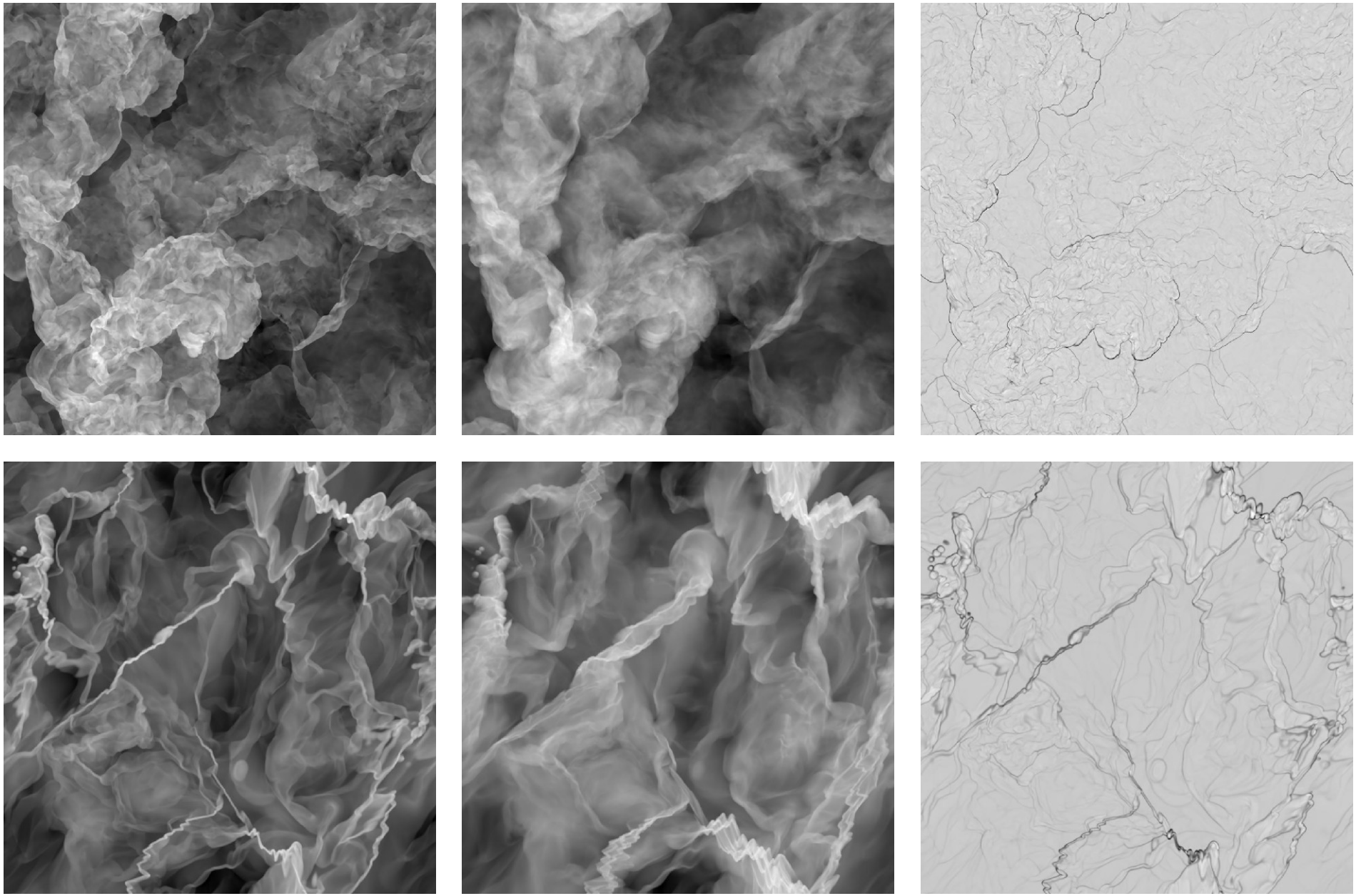
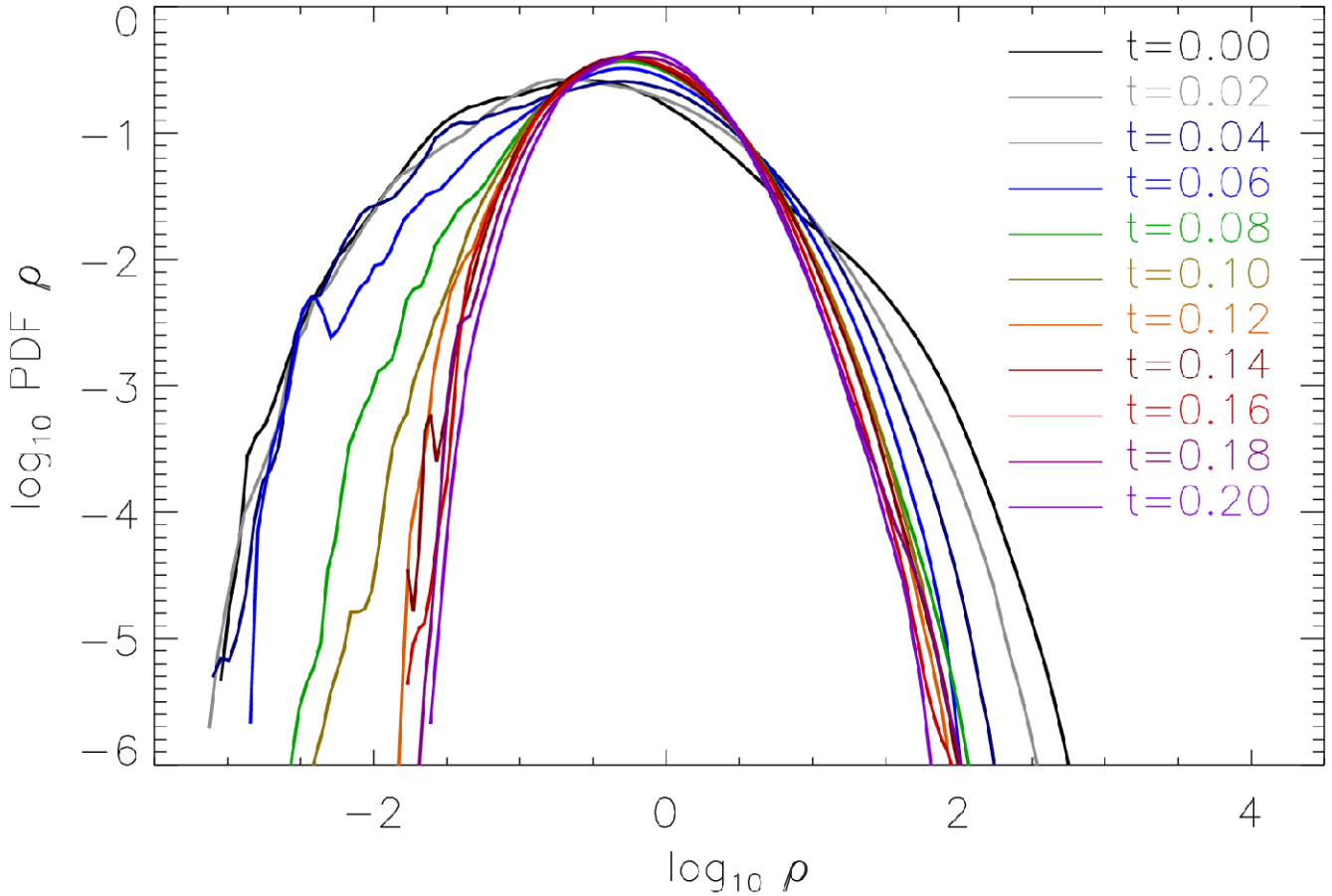




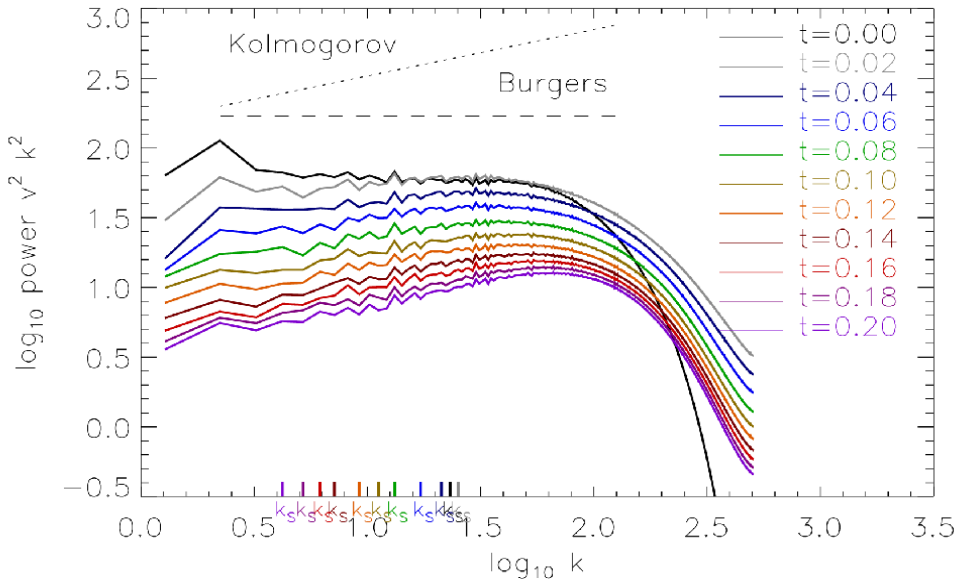
FLASH results – 1024^3 polytropic eos rho z-slice, 5% z-slice, divV z-slice

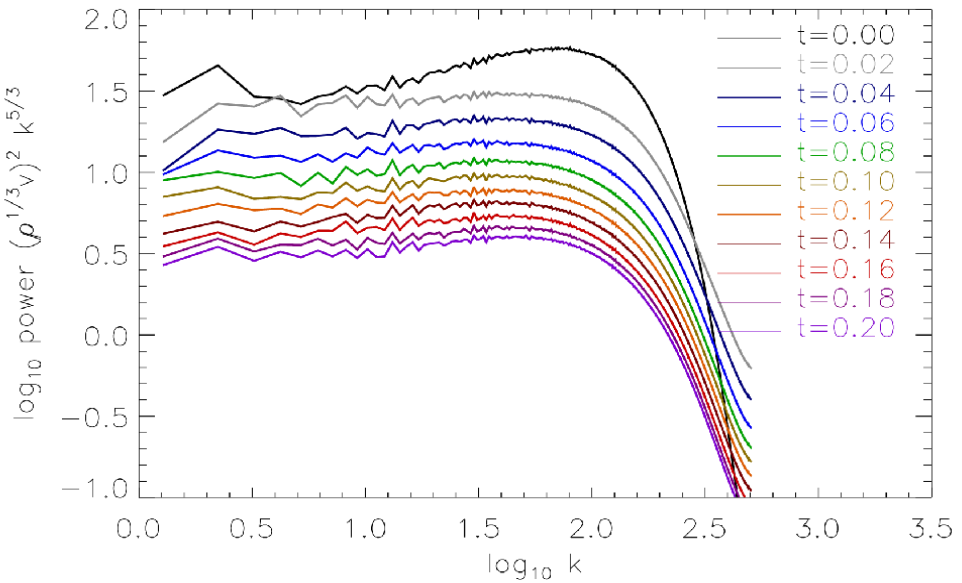


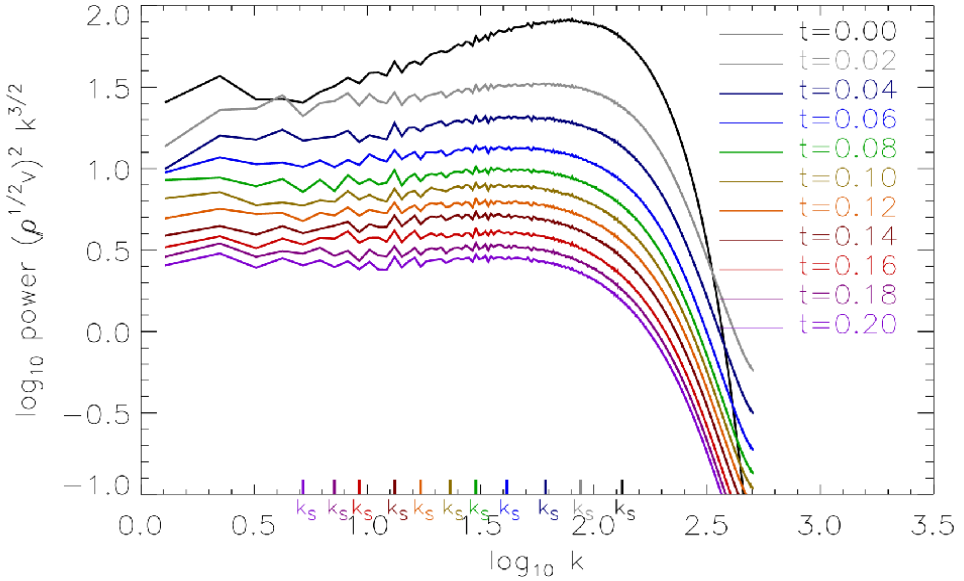
FLASH results – 1024^3 polytropic eos density PDF

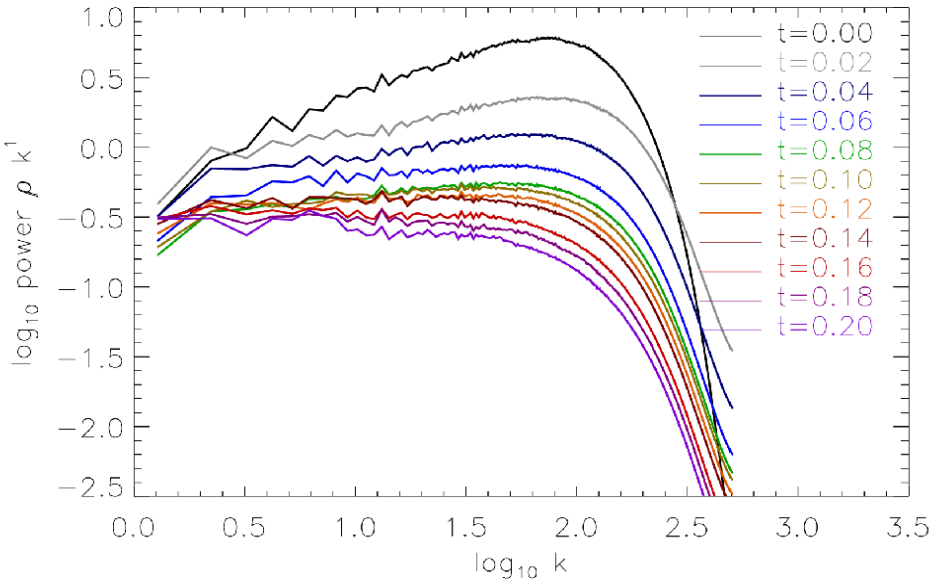


FLASH results – 1024^3 polytropic eos power spectra



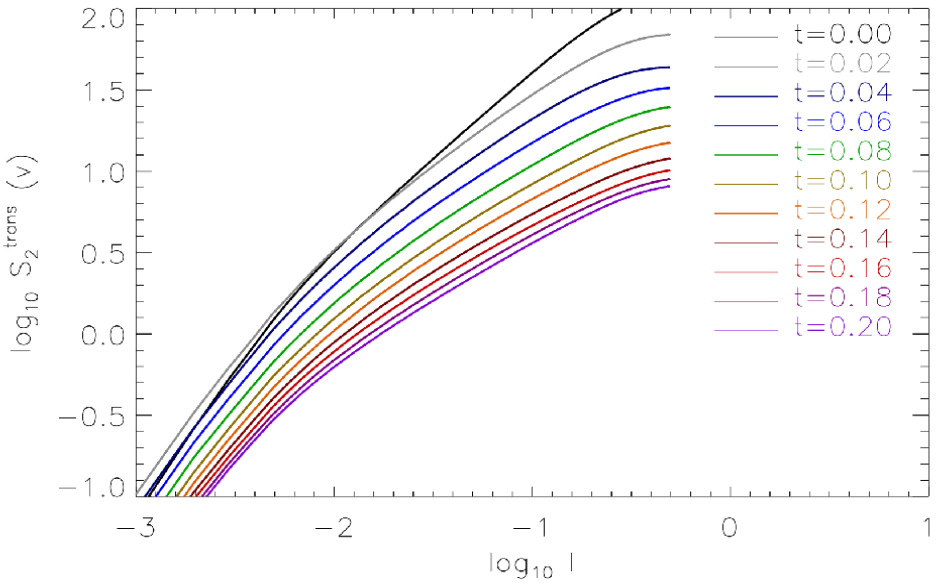




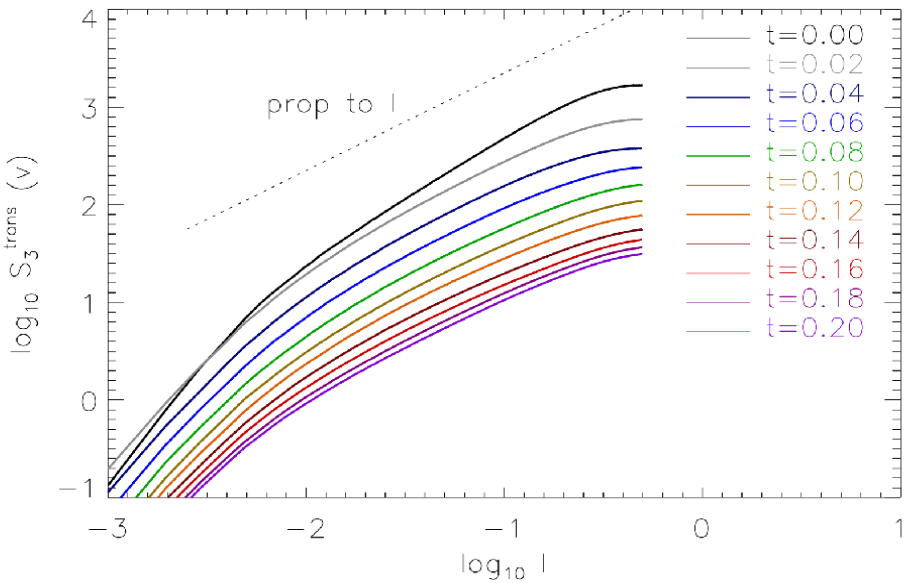


FLASH results – 1024^3 polytropic eos structure functions

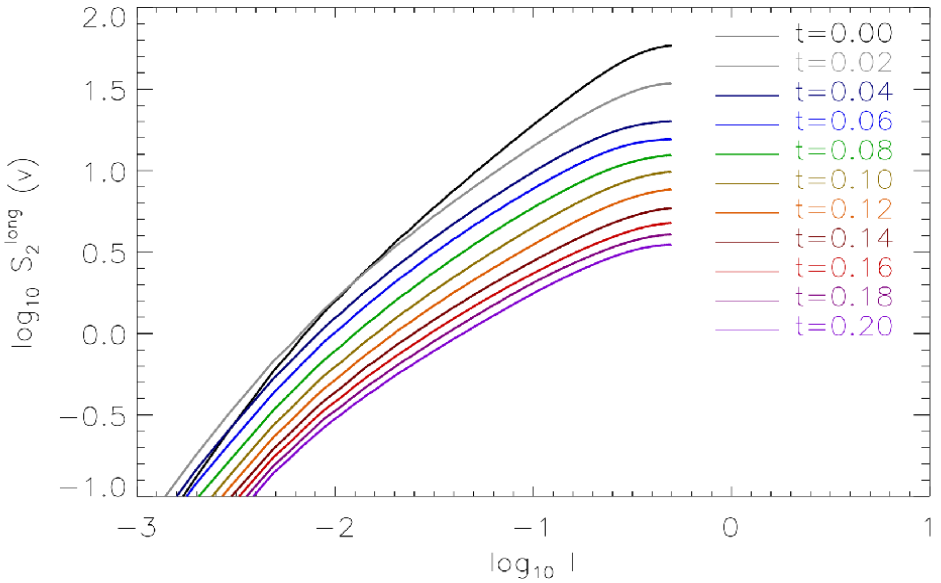
2nd order transversal



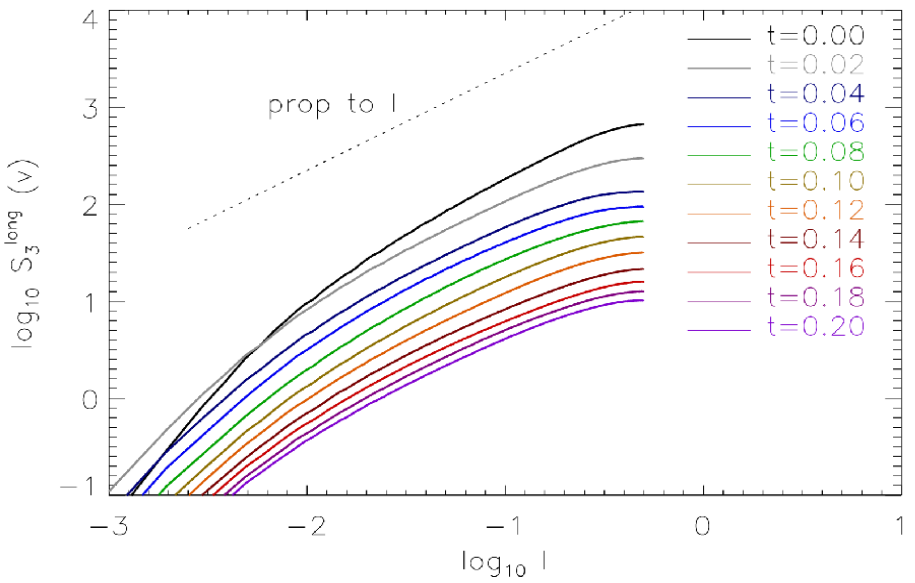
3rd order transversal



2nd order longitudinal



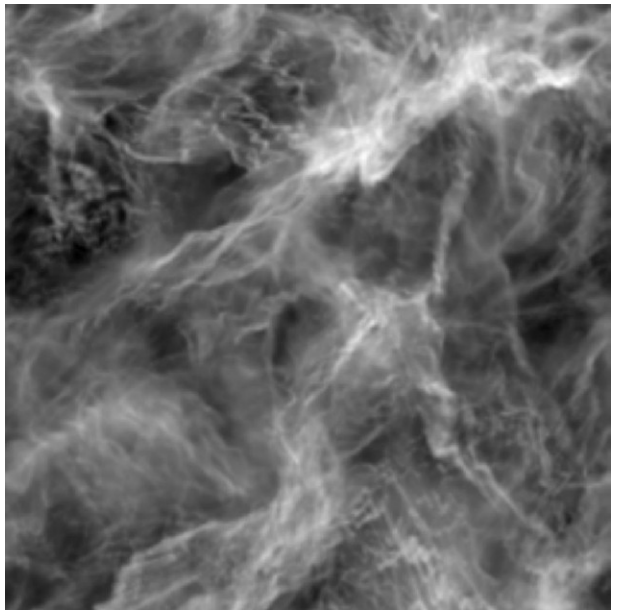
3rd order longitudinal

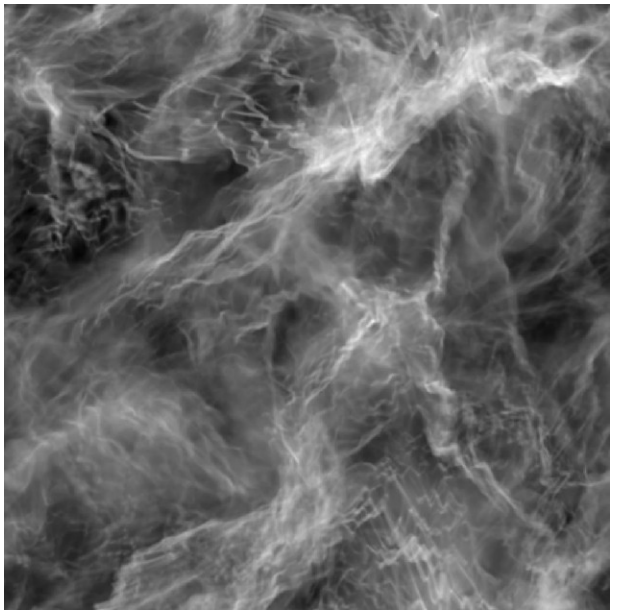


FLASH results – resolution study column density z

t = 0.00

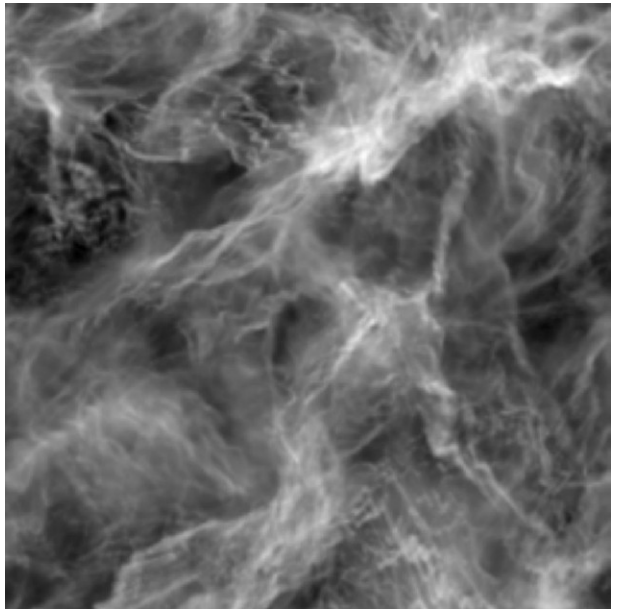
256^3
gamma=1.001

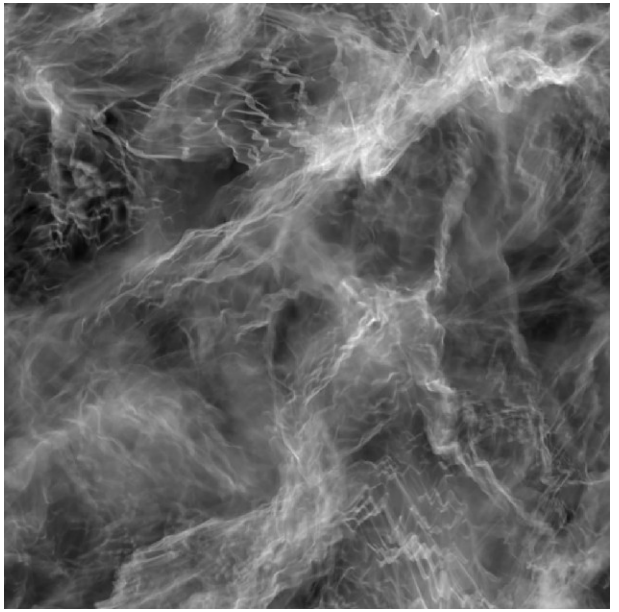




512^3
polytropic eos

256^3
polytropic eos



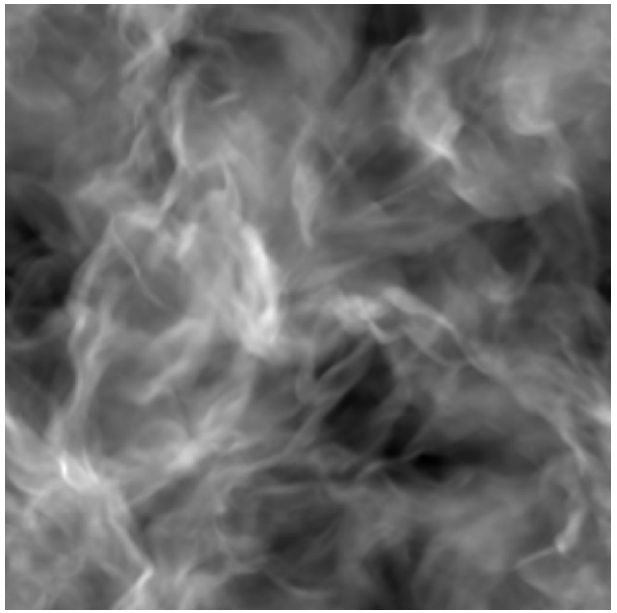


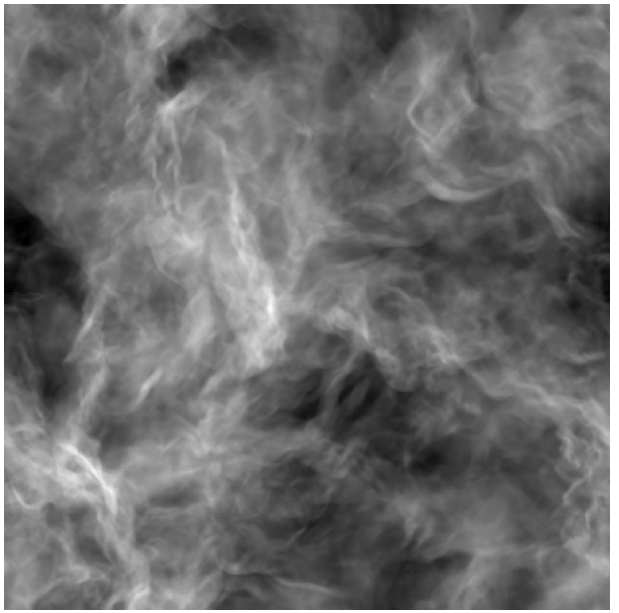
1024^3
polytropic eos

FLASH results – resolution study column density z

t = 0.10

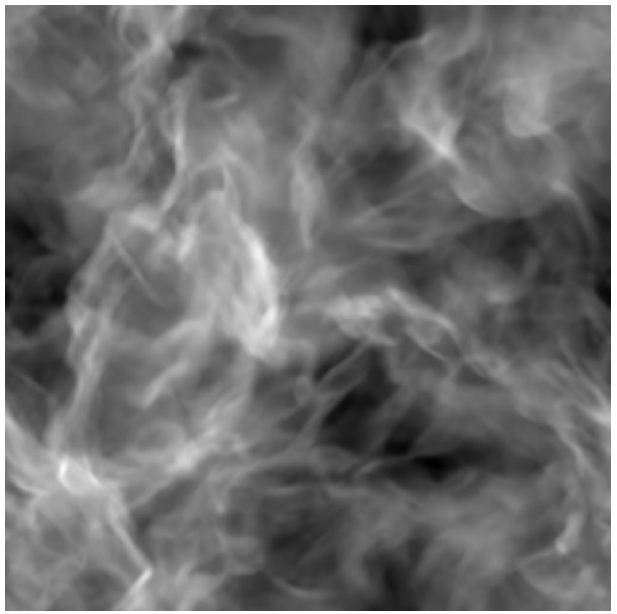
256^3
gamma=1.001

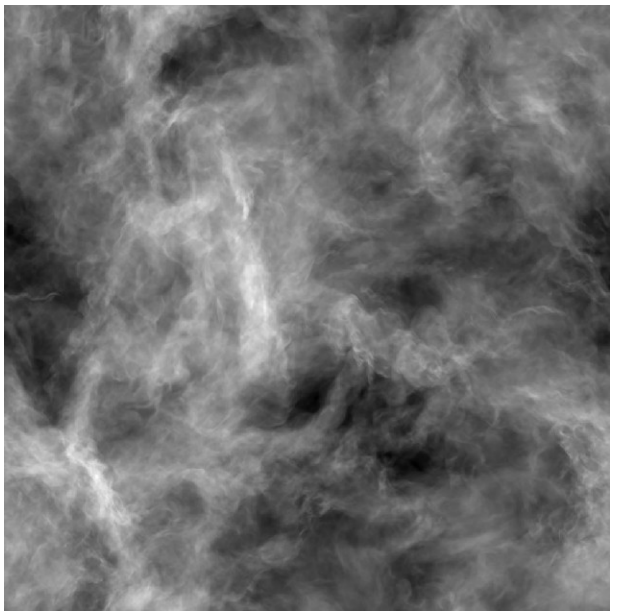




512^3
polytropic eos

256^3
polytropic eos



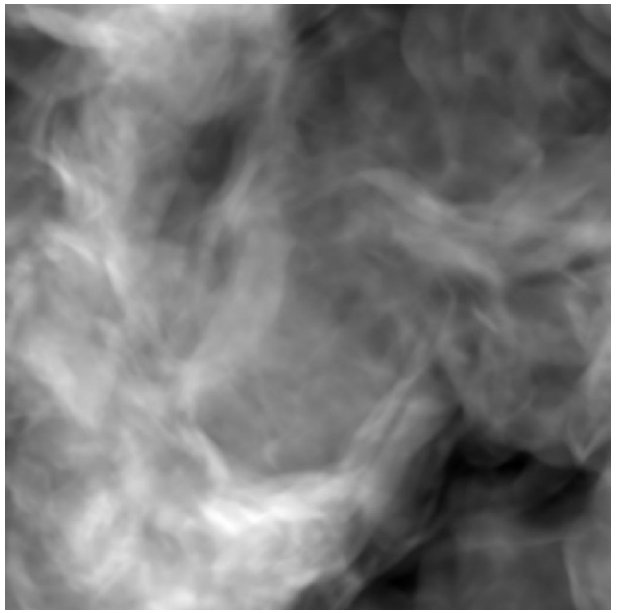


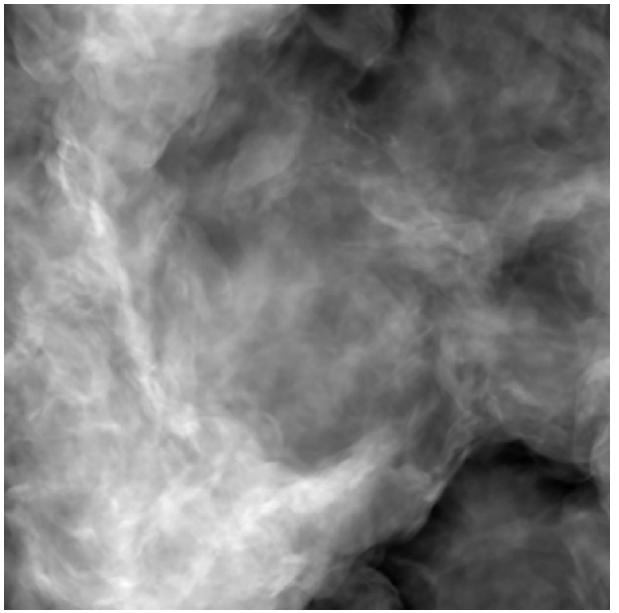
1024^3
polytropic eos

FLASH results – resolution study column density z

t = 0.20

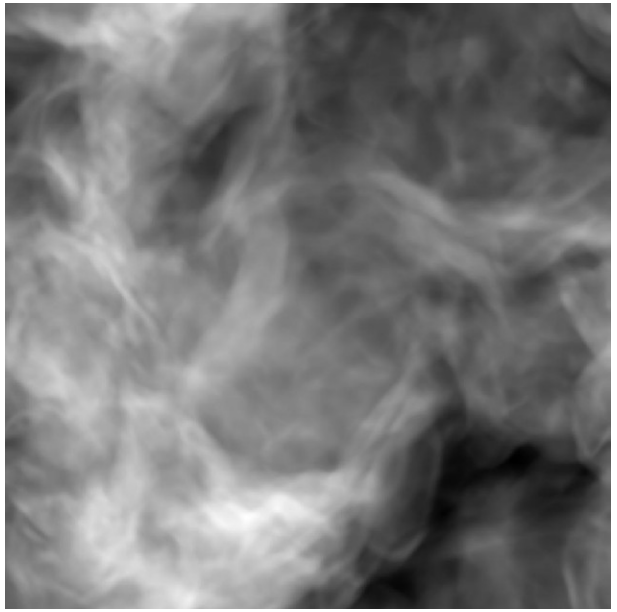
256^3
gamma=1.001

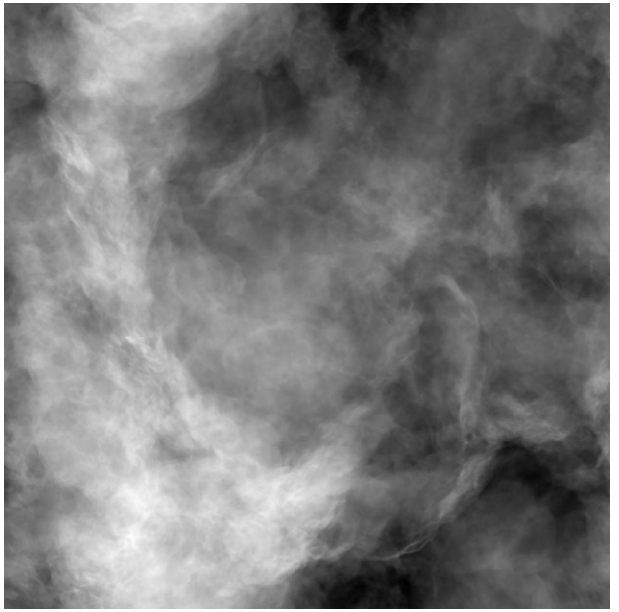




512^3
polytropic eos

256^3
polytropic eos



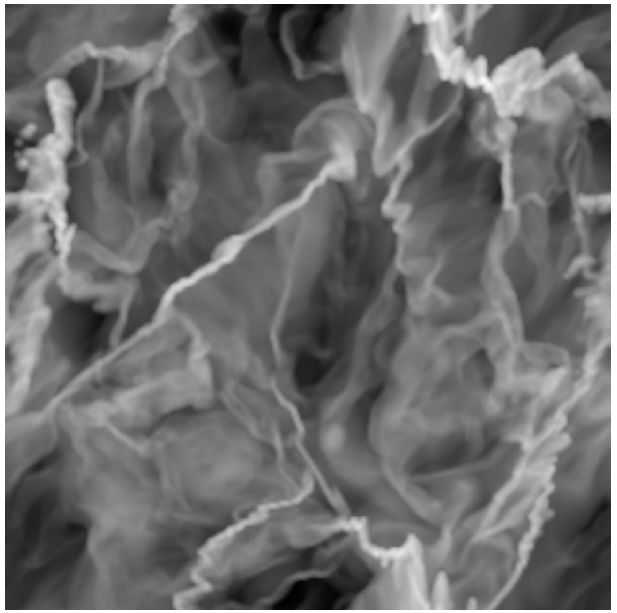


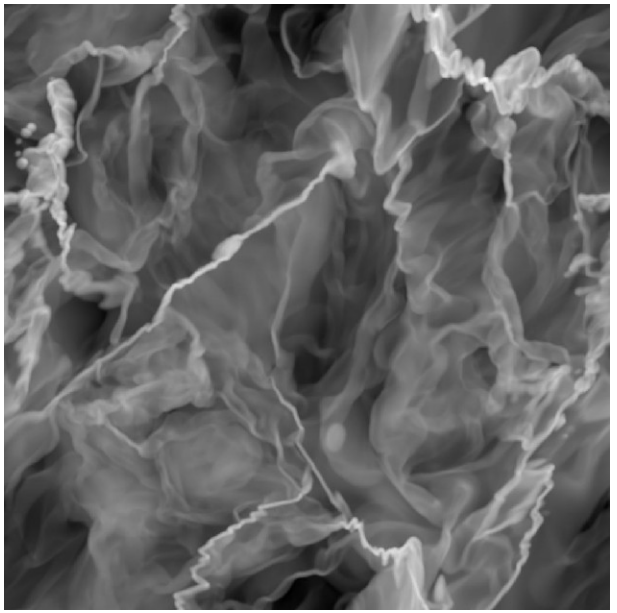
1024^3
polytropic eos

FLASH results – resolution study rho z-slice

t = 0.00

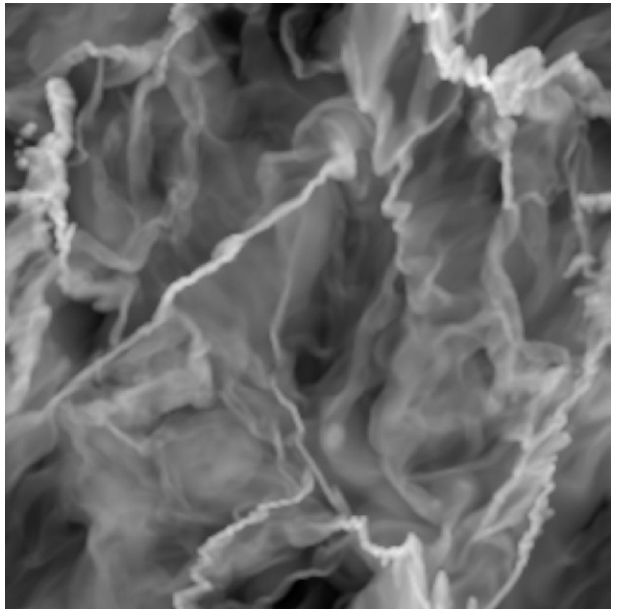
256^3
gamma=1.001

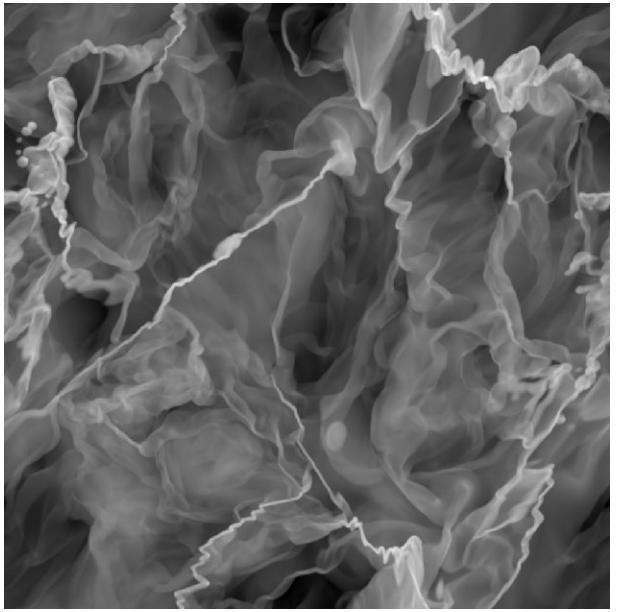




512^3
polytropic eos

256^3
polytropic eos



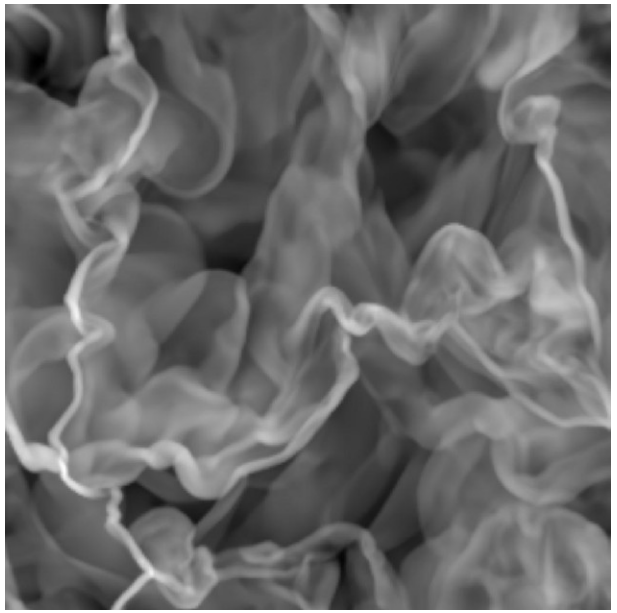


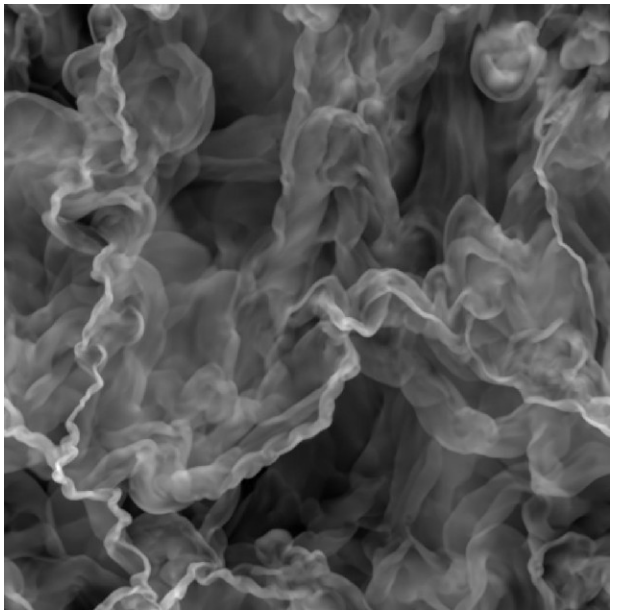
1024^3
polytropic eos

FLASH results – resolution study rho z-slice

t = 0.10

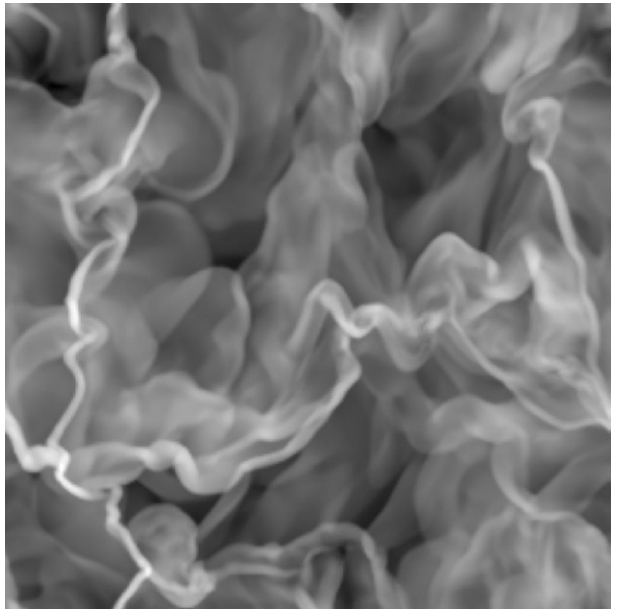
256^3
gamma=1.001

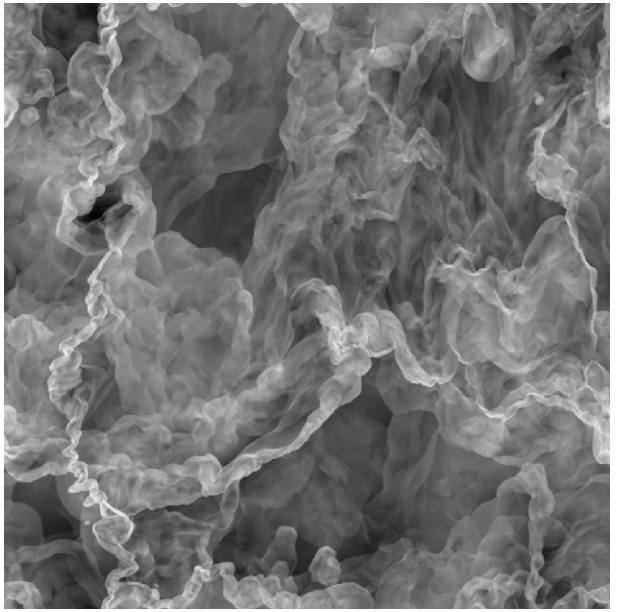




512^3
polytropic eos

256^3
polytropic eos



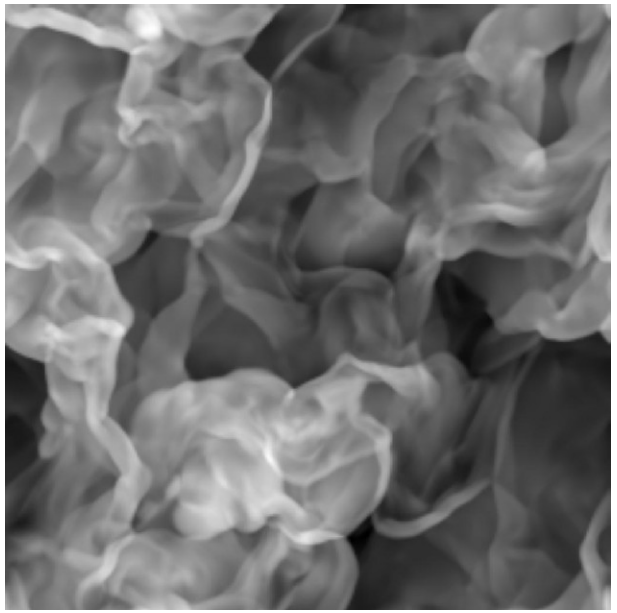


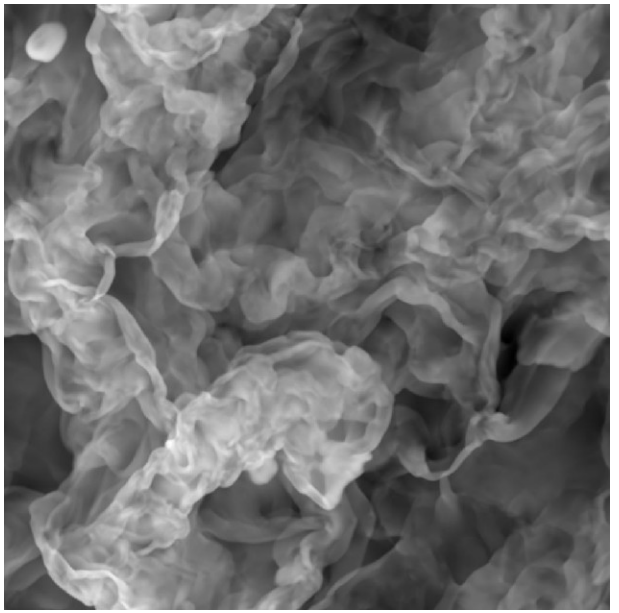
1024^3
polytropic eos

FLASH results – resolution study rho z-slice

t = 0.20

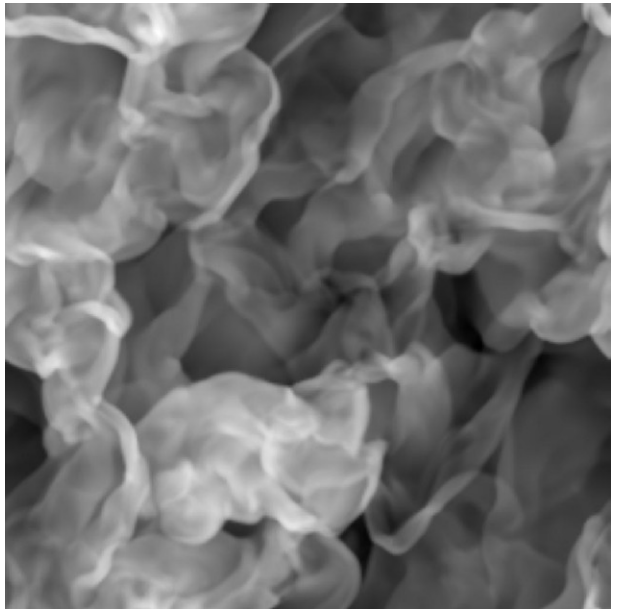
256^3
gamma=1.001

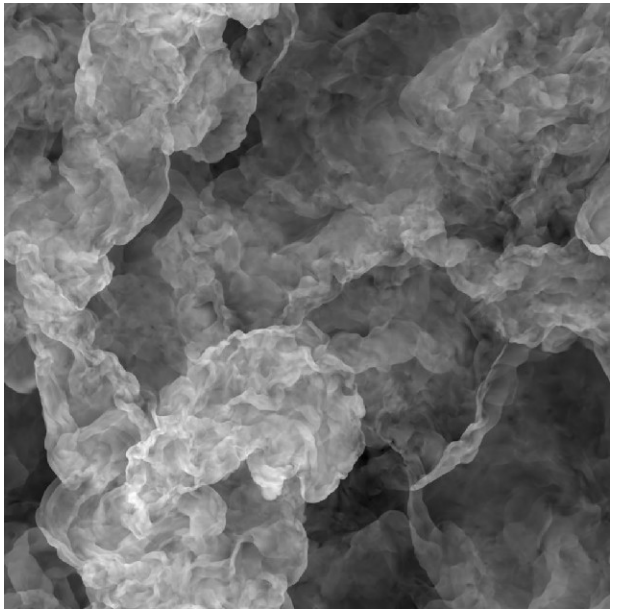




512^3
polytropic eos

256^3
polytropic eos



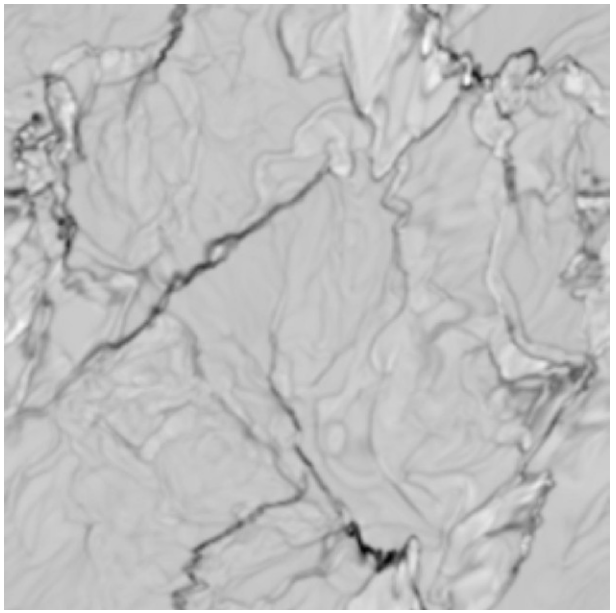


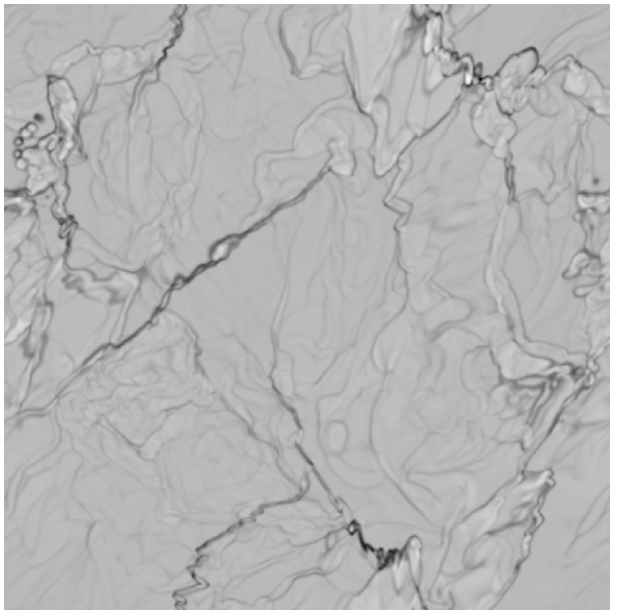
1024^3
polytropic eos

FLASH results – resolution study divV z-slice

t = 0.00

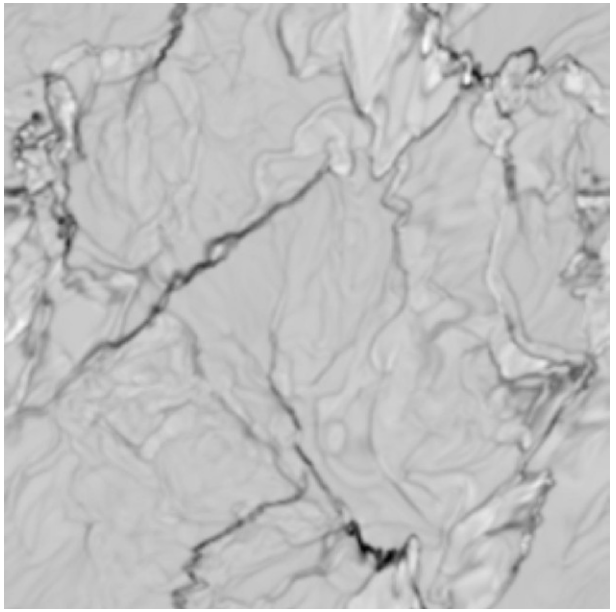
256^3
gamma=1.001

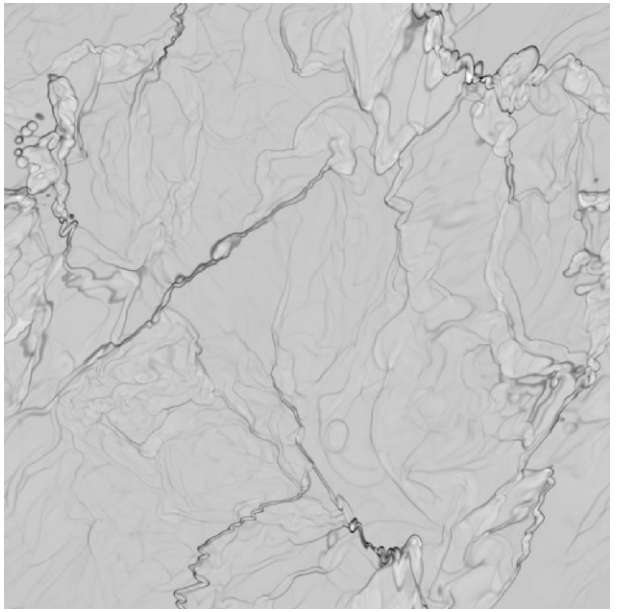




512^3
polytropic eos

256^3
polytropic eos



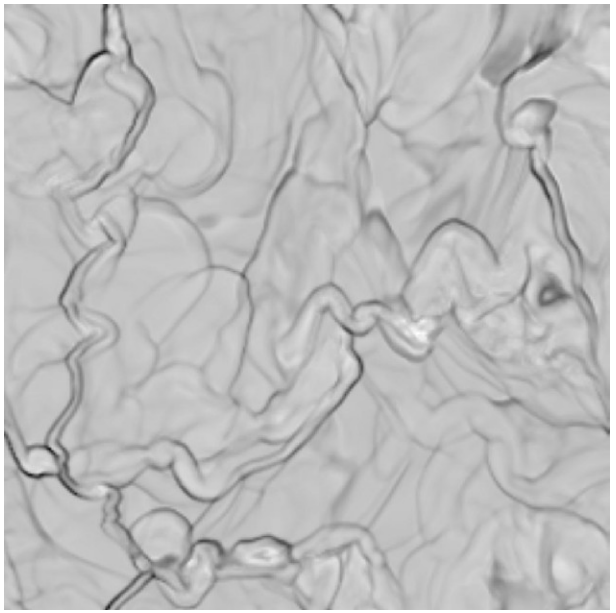


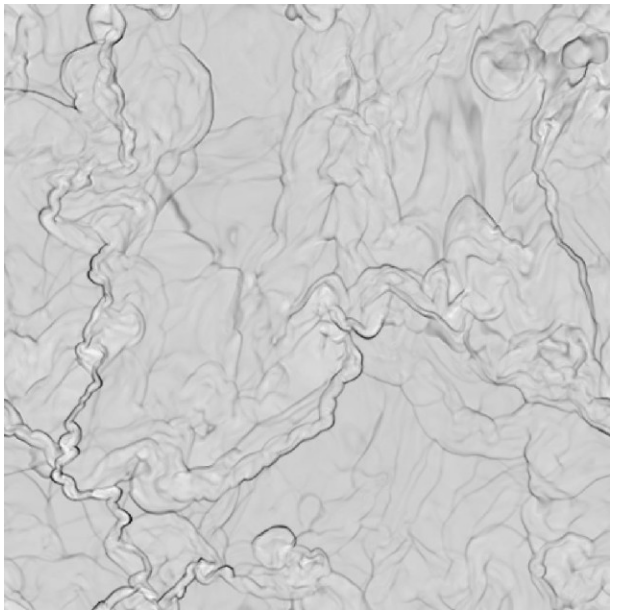
1024^3
polytropic eos

FLASH results – resolution study divV z-slice

t = 0.10

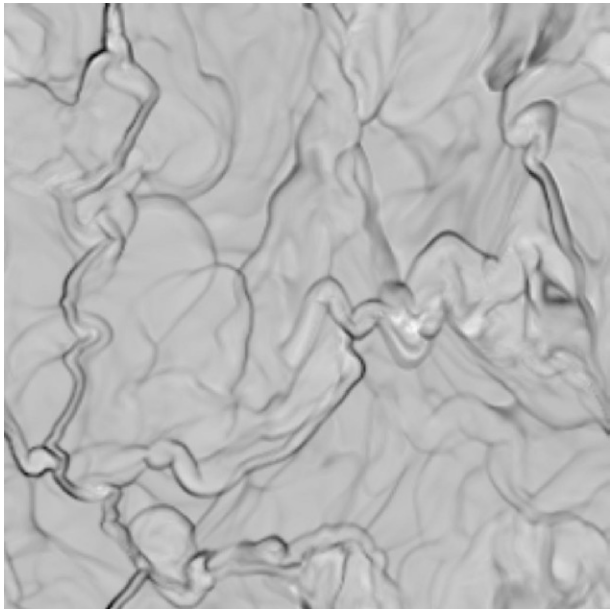
256^3
gamma=1.001

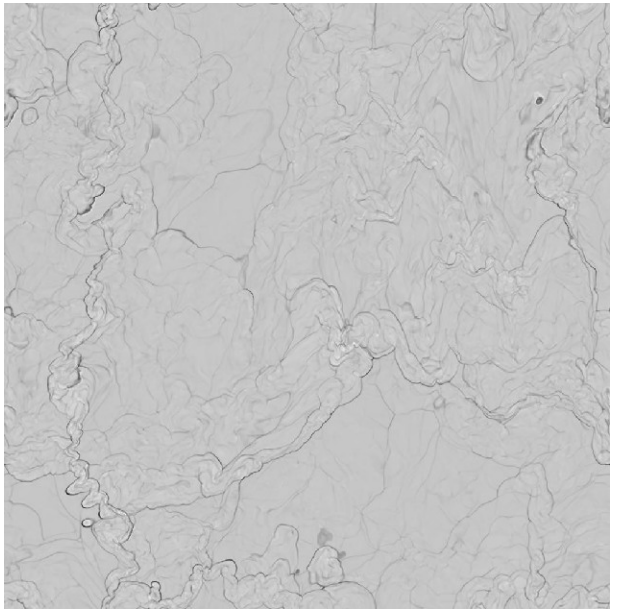




512^3
polytropic eos

256^3
polytropic eos



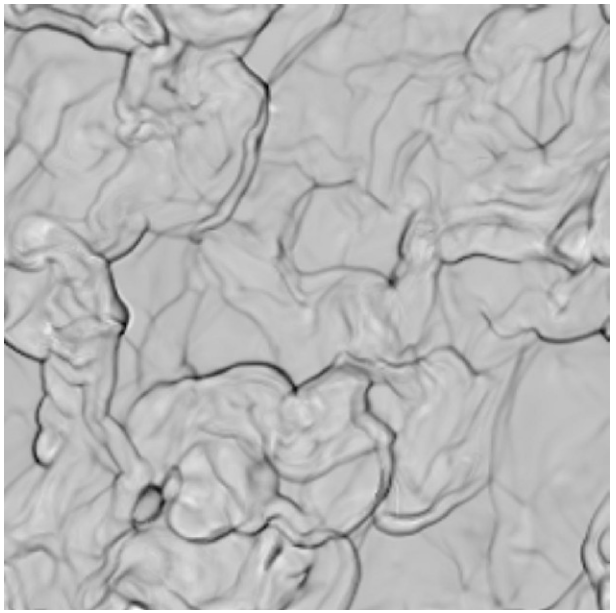


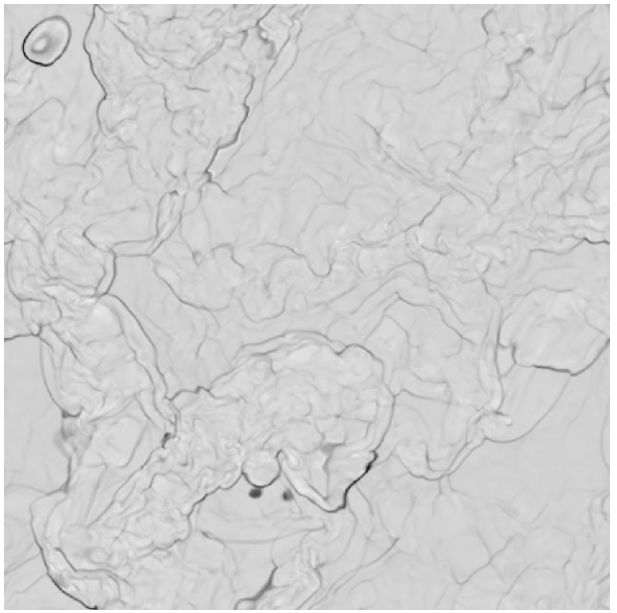
1024^3
polytropic eos

FLASH results – resolution study divV z-slice

t = 0.20

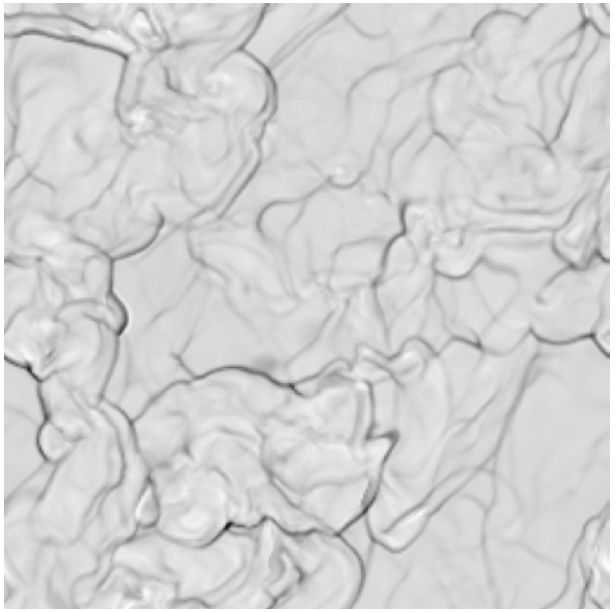
256^3
gamma=1.001





512^3
polytropic eos

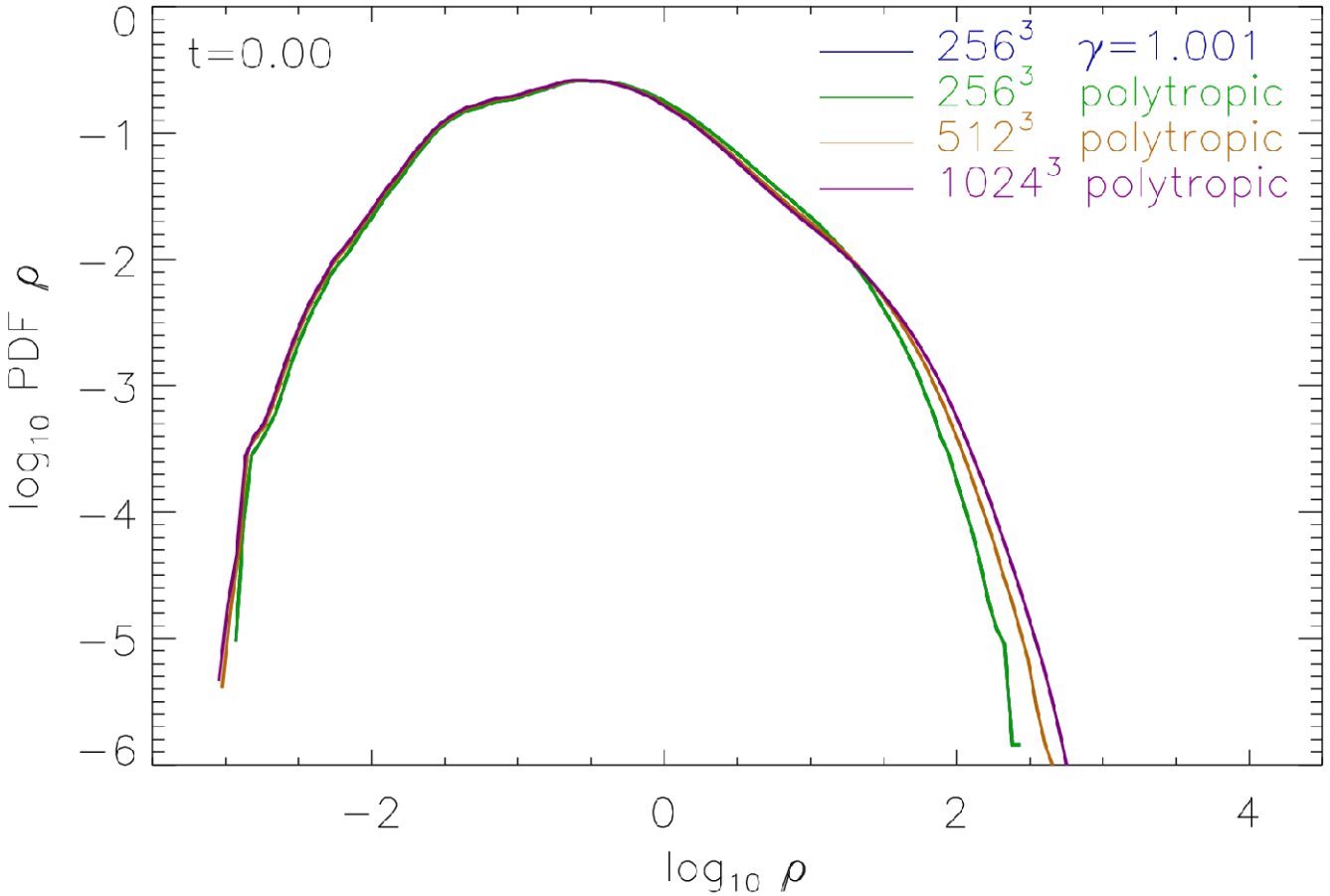
256^3
polytropic eos



1024^3
polytropic eos

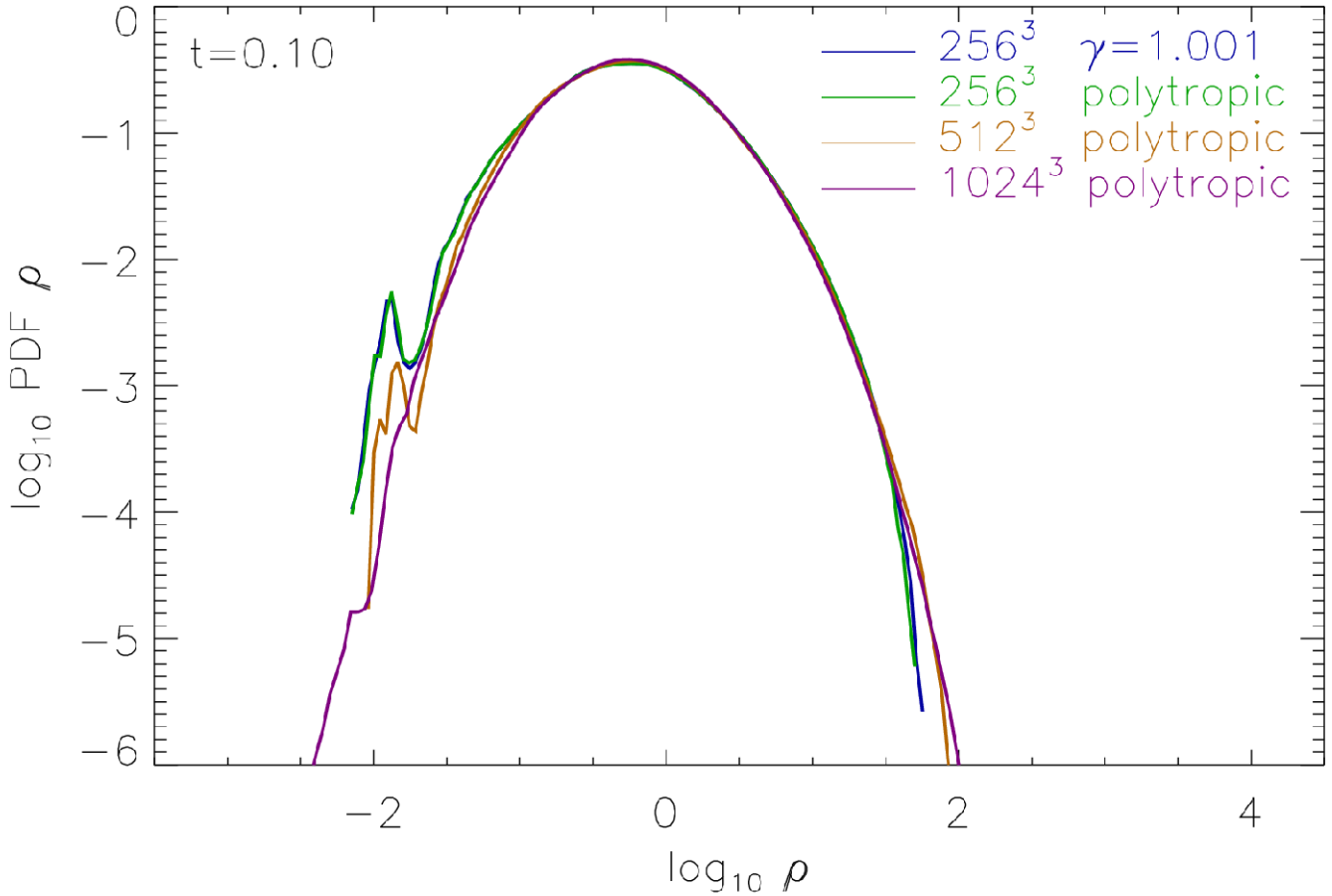
FLASH results – resolution study density PDF

t = 0.00



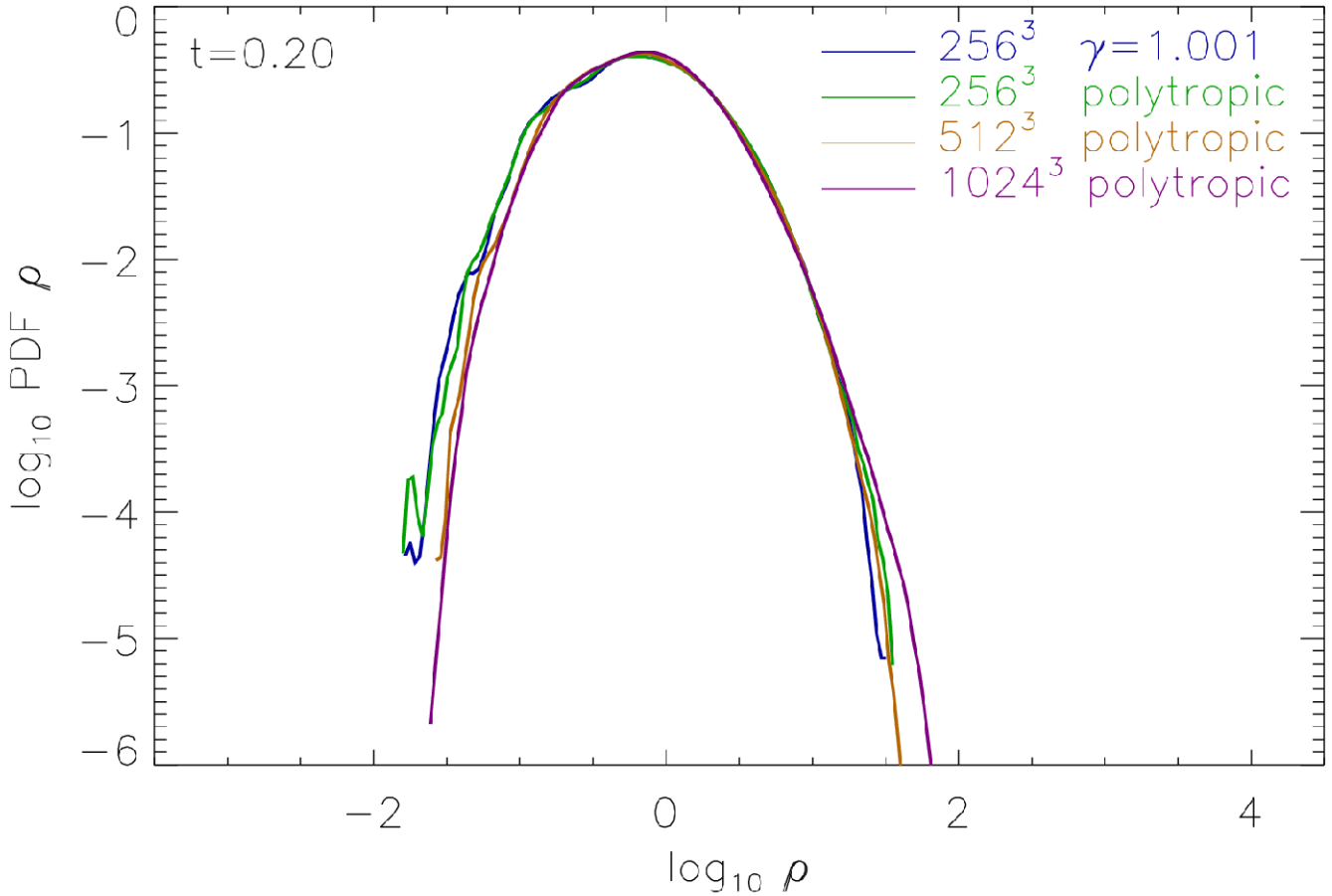
FLASH results – resolution study density PDF

t = 0.10



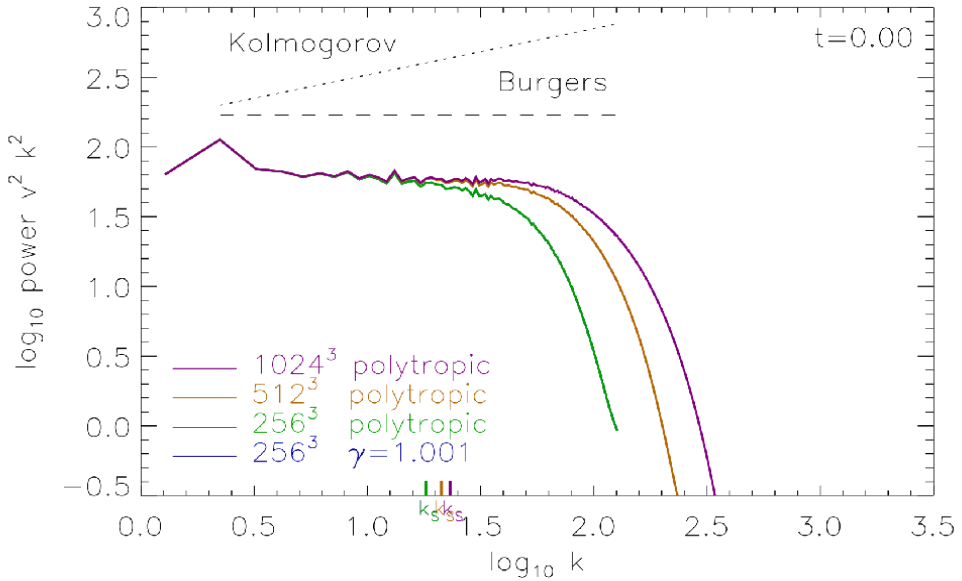
FLASH results – resolution study density PDF

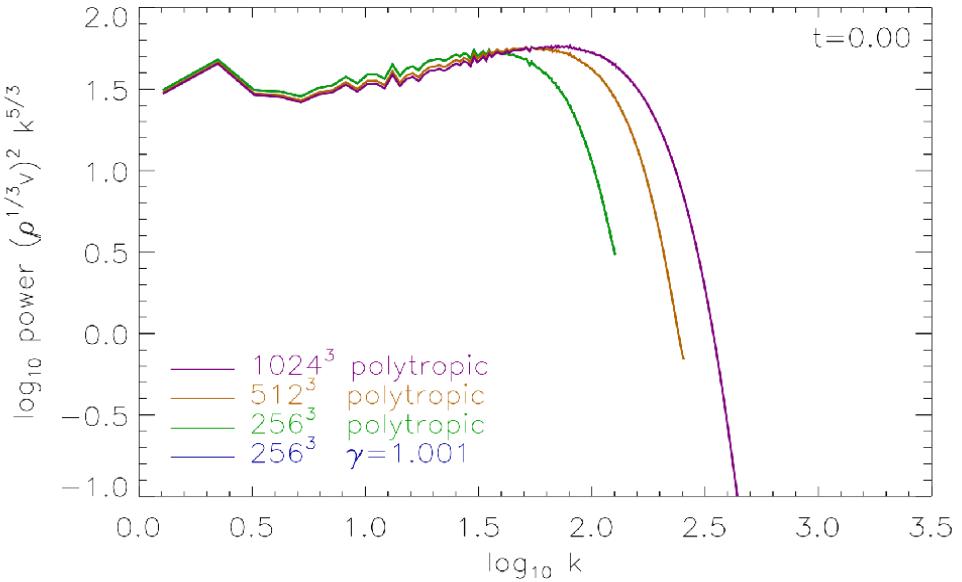
t = 0.20

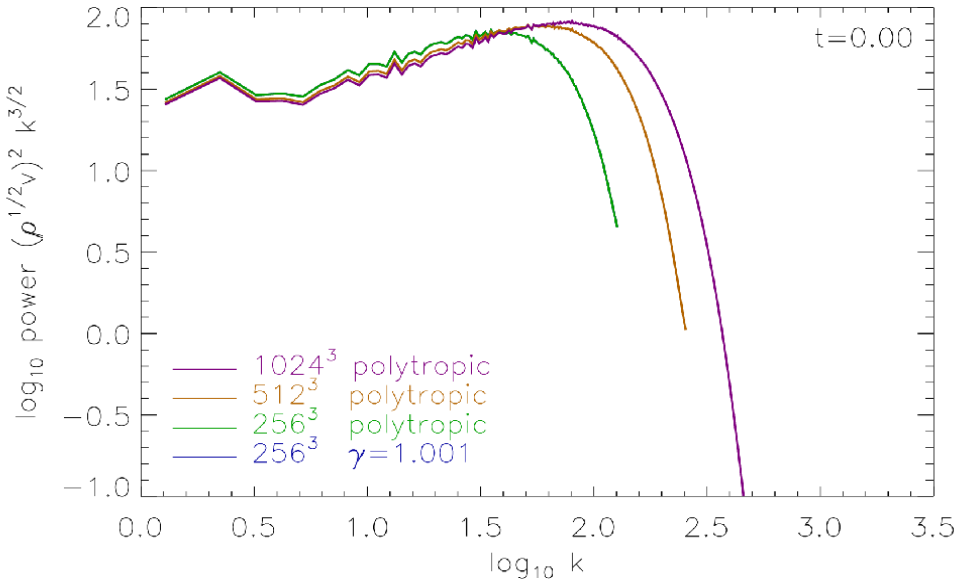


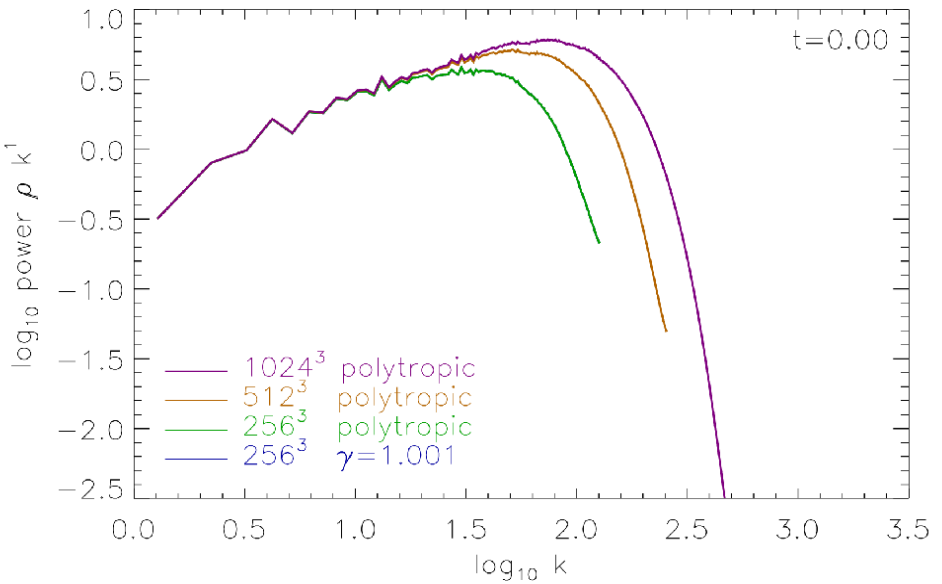
FLASH results – resolution study power spectra

t = 0.00



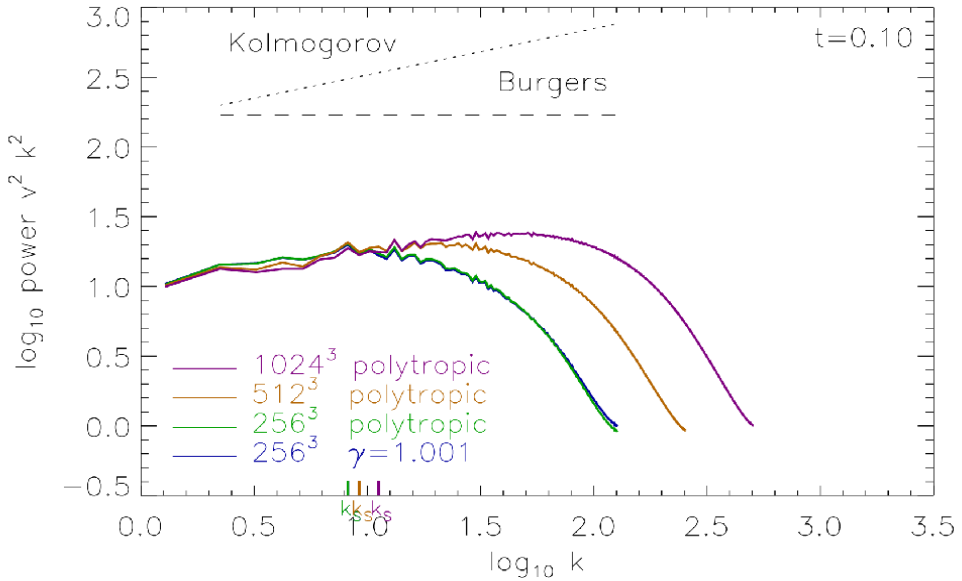


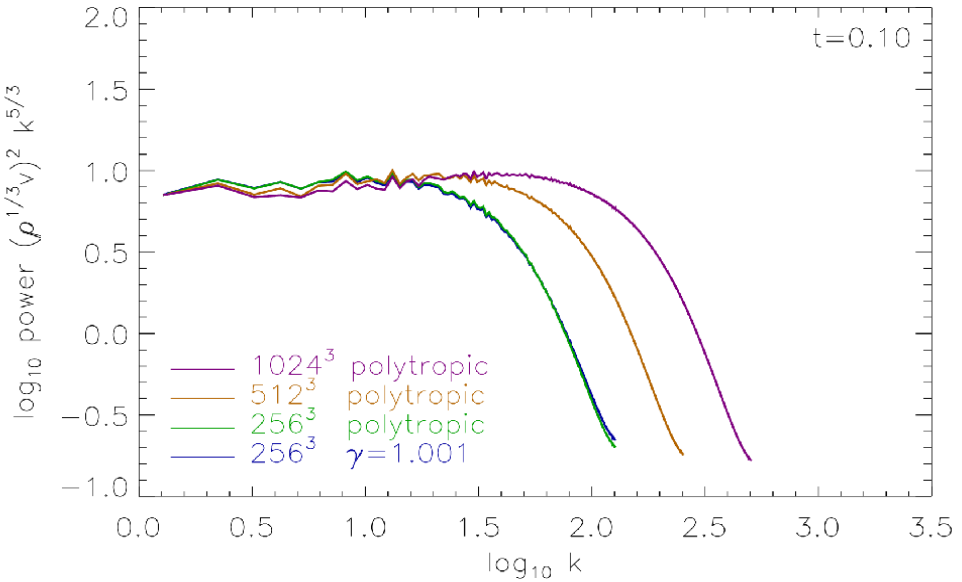


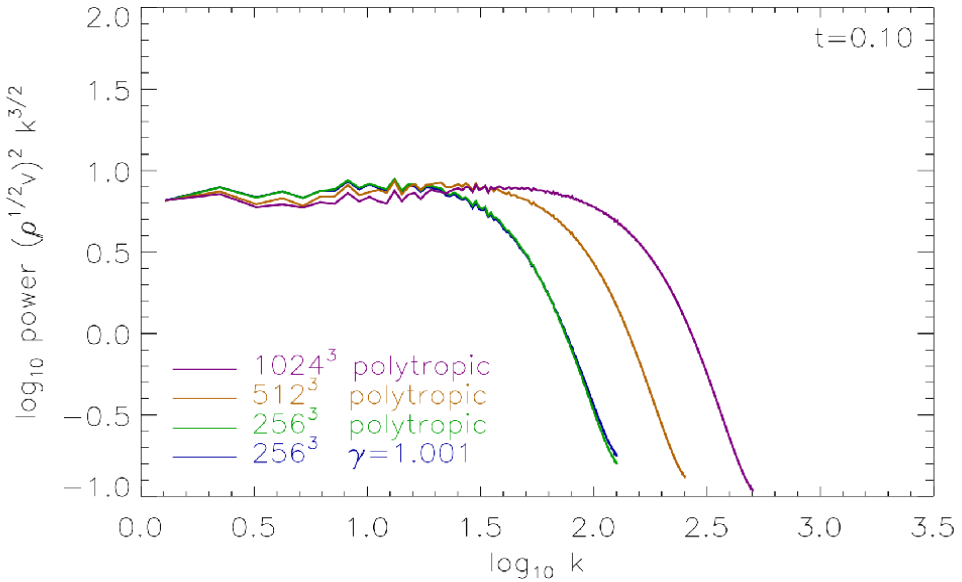


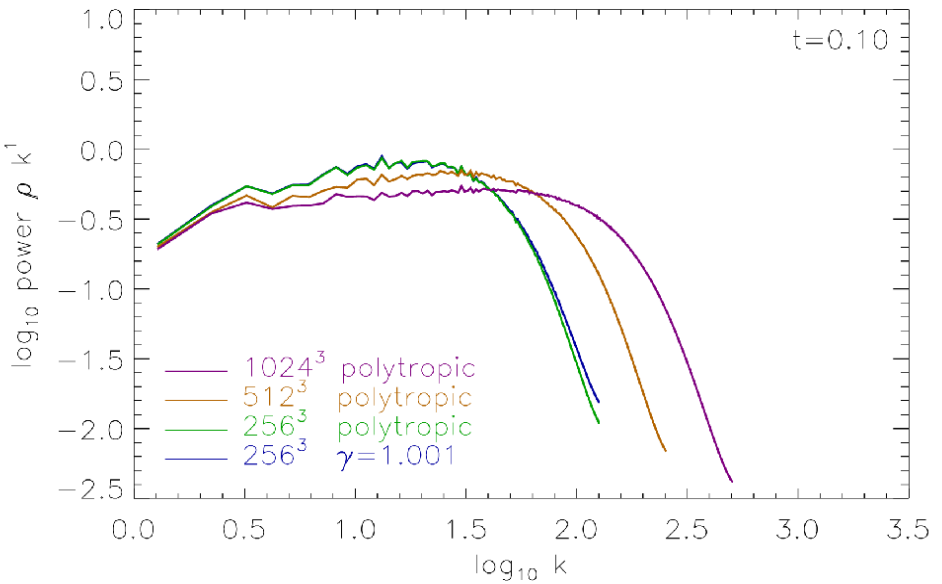
FLASH results – resolution study power spectra

t = 0.10



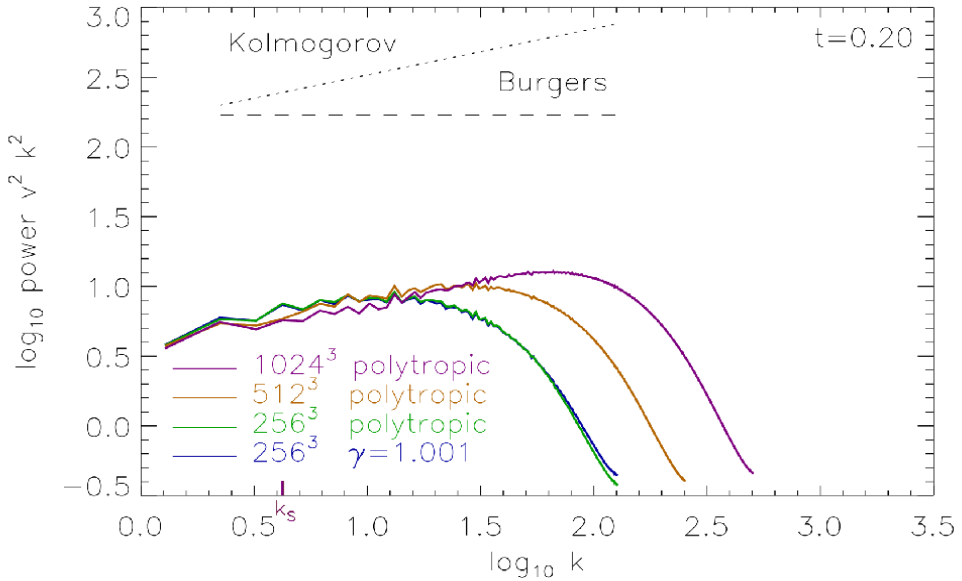


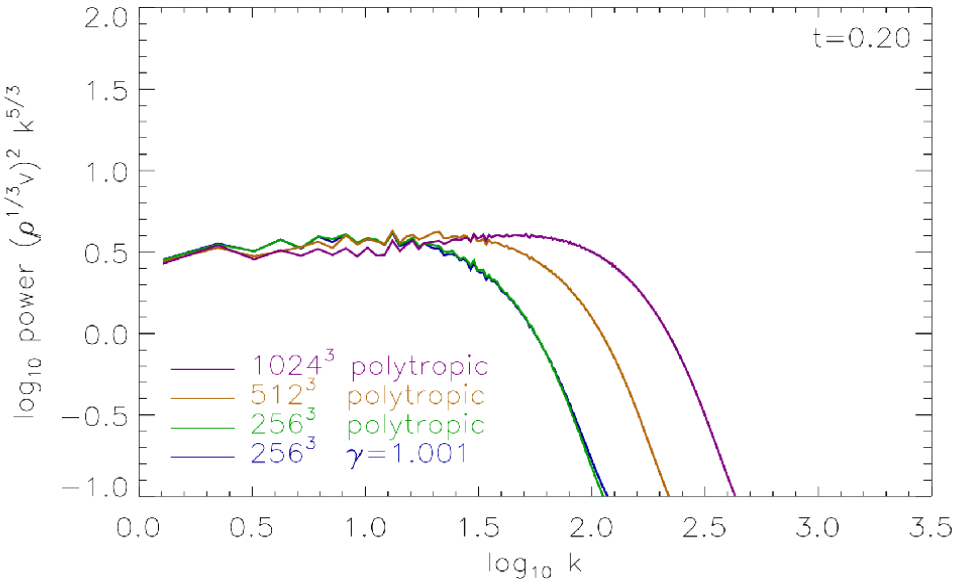


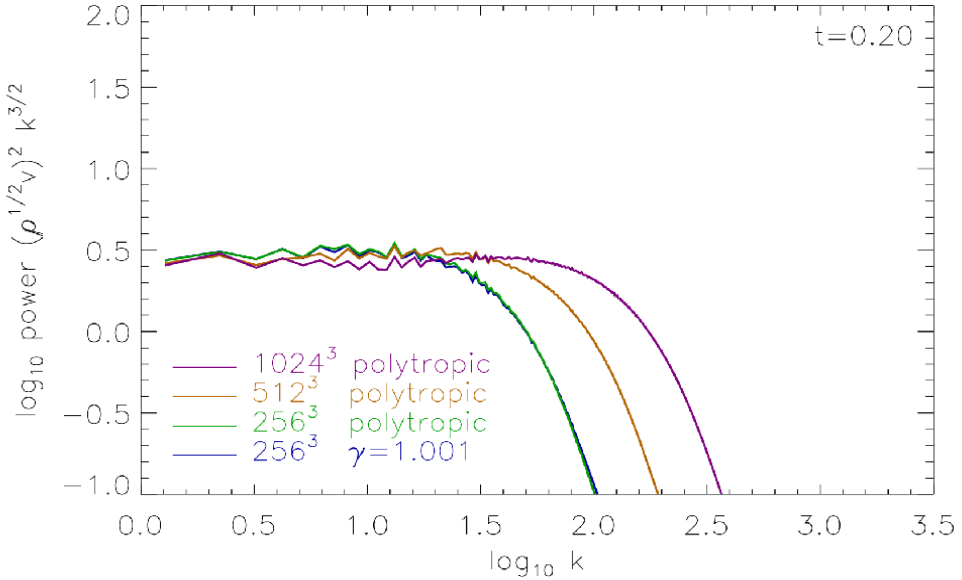


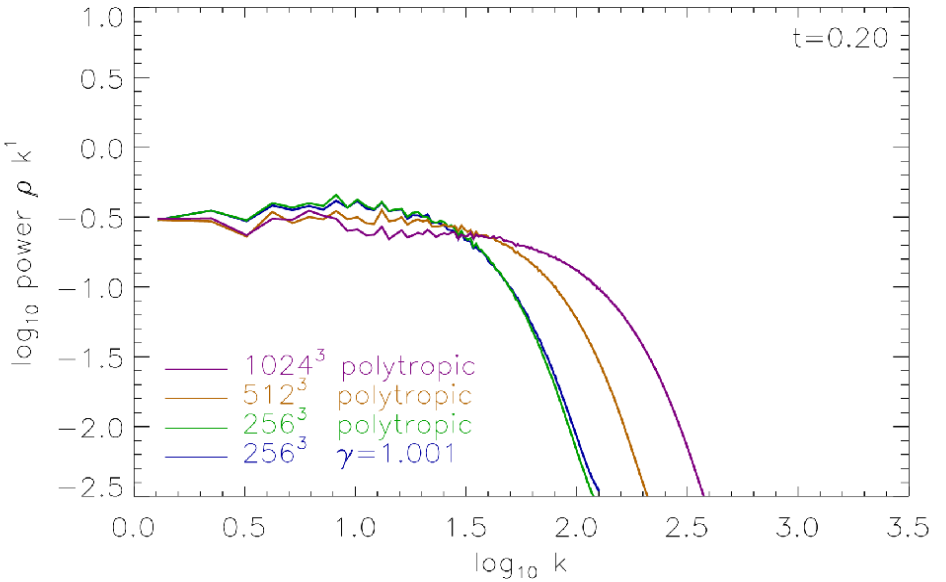
FLASH results – resolution study power spectra

t = 0.20





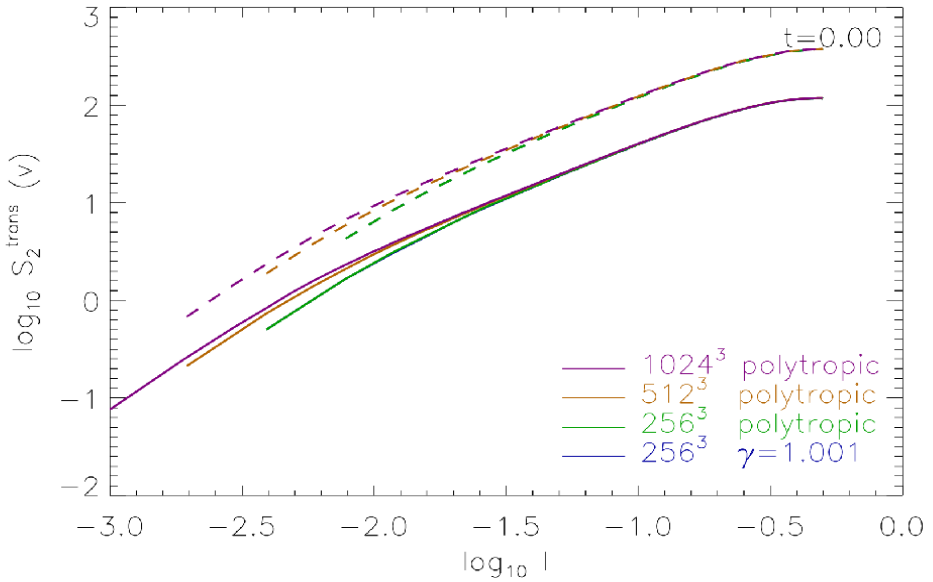




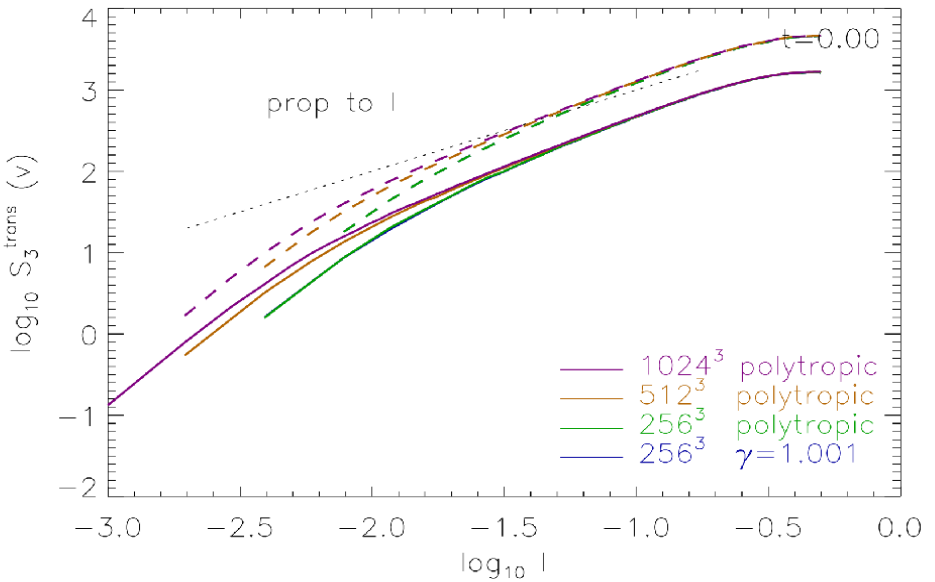
FLASH results – resolution study structure functions

t = 0.00

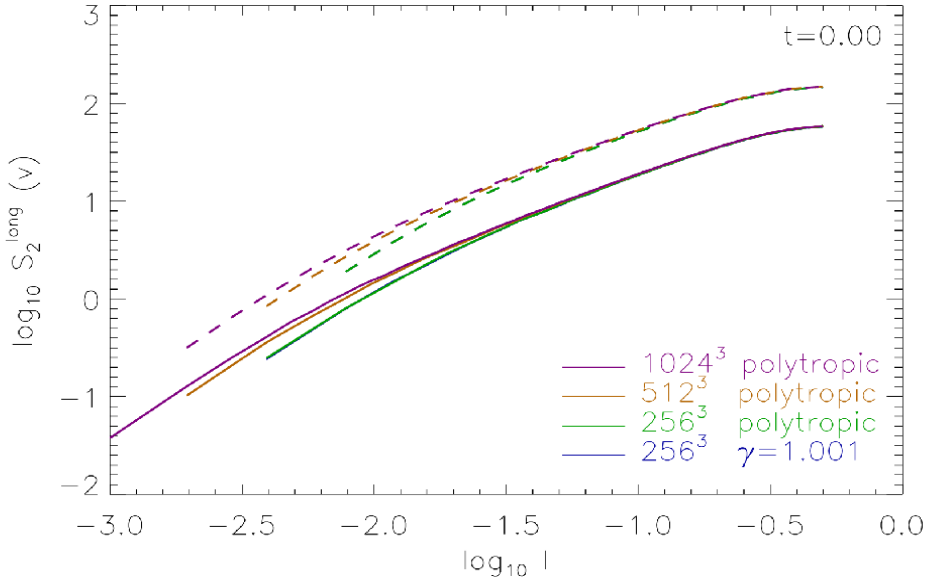
2nd order transversal



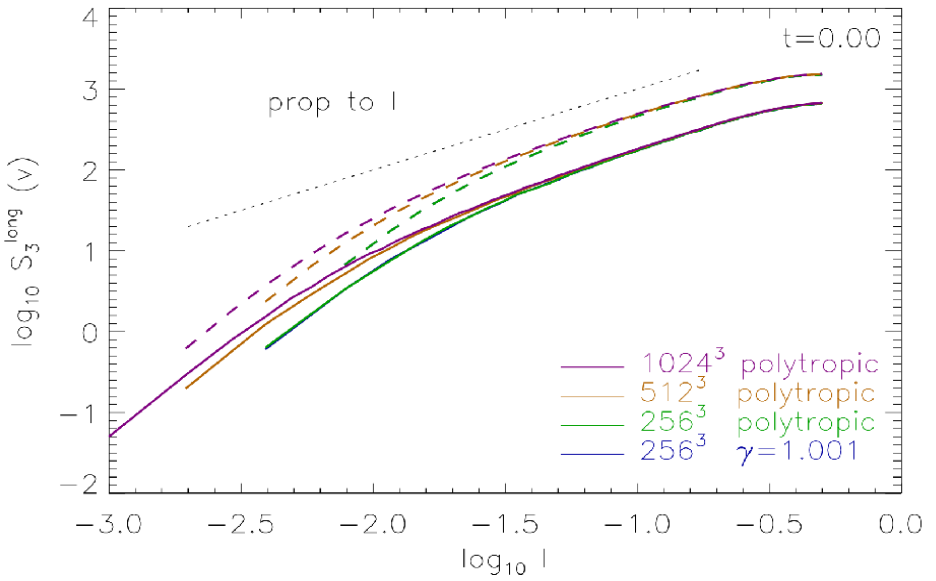
3rd order transversal



2nd order longitudinal



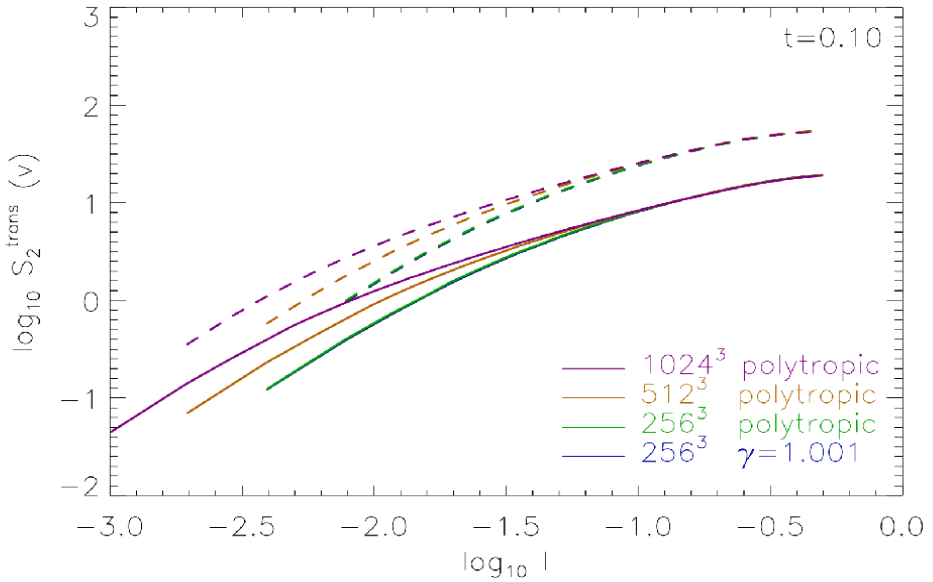
3rd order longitudinal



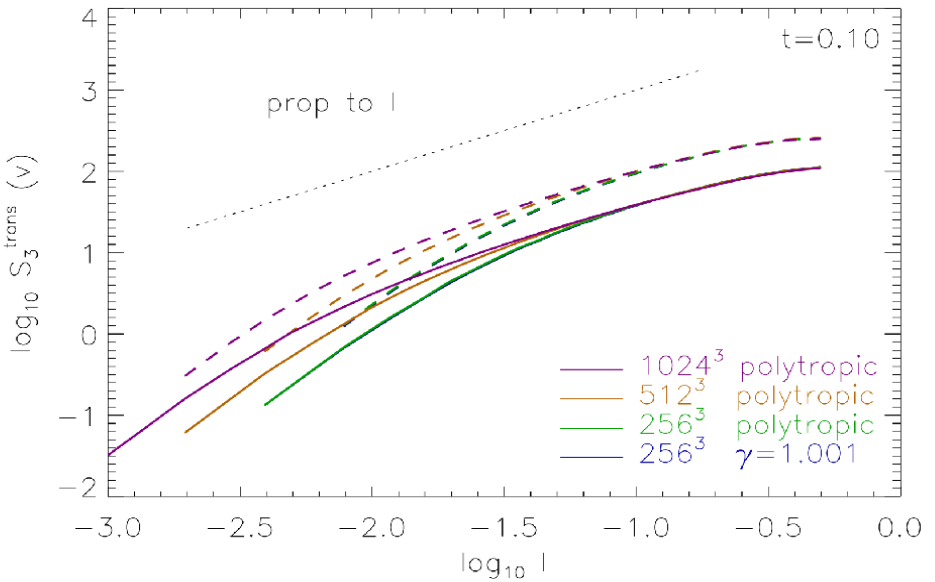
FLASH results – resolution study structure functions

t = 0.10

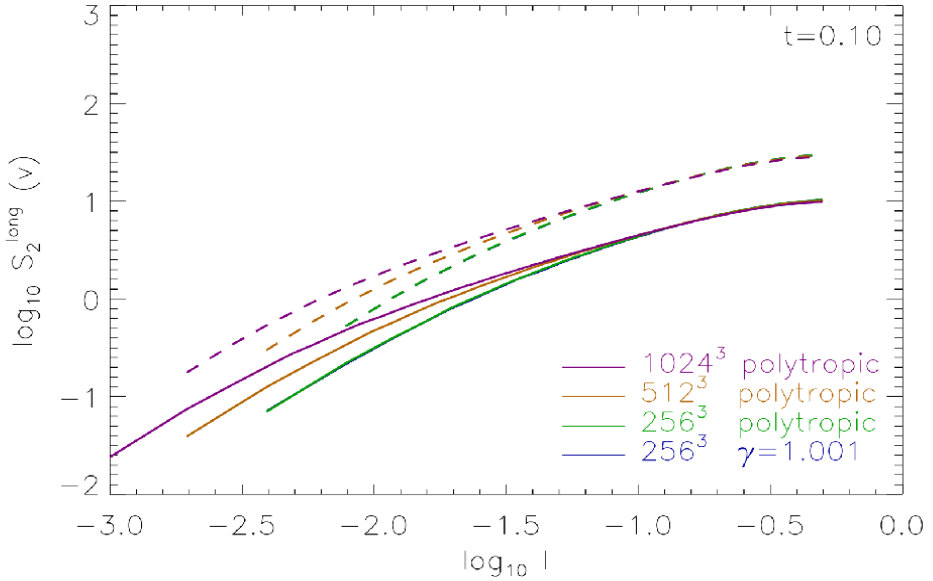
2nd order transversal



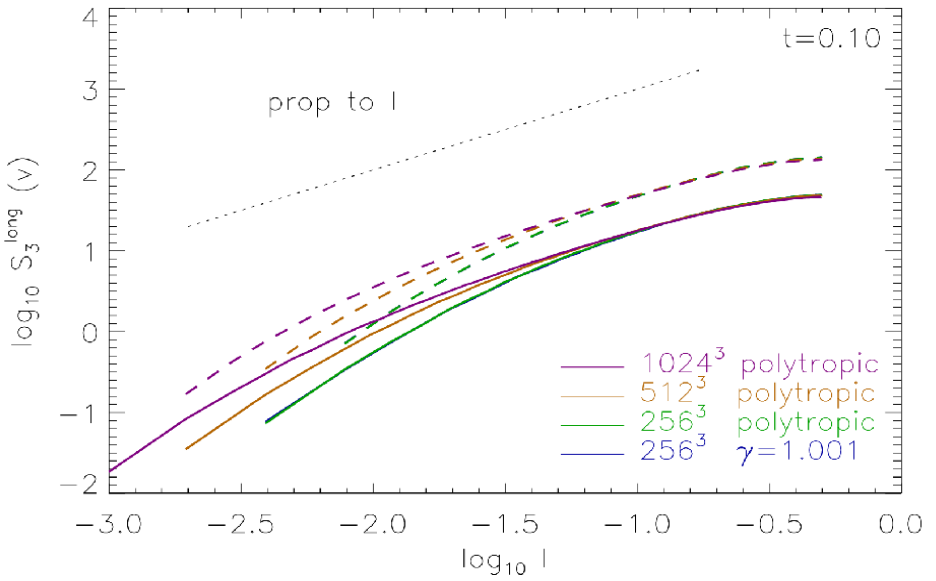
3rd order transversal



2nd order longitudinal



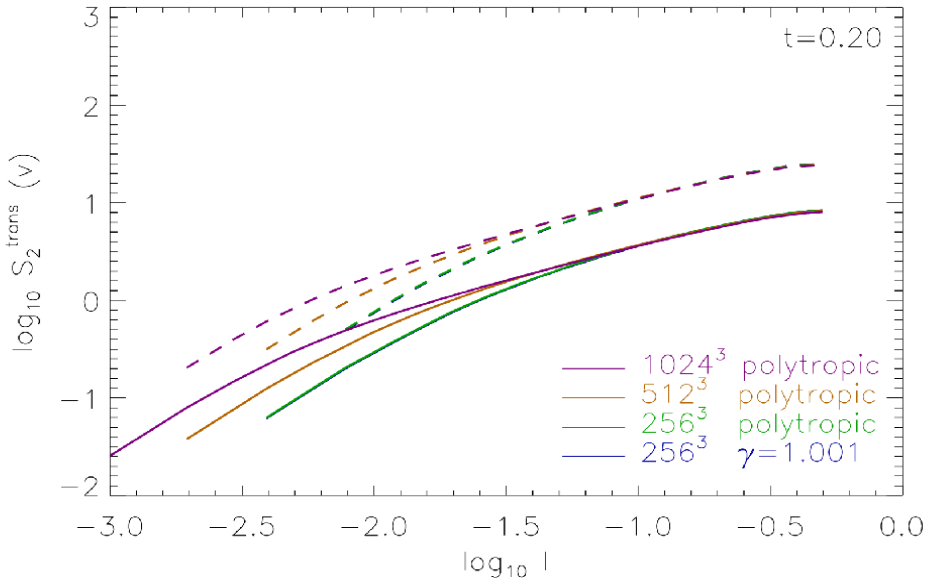
3rd order longitudinal



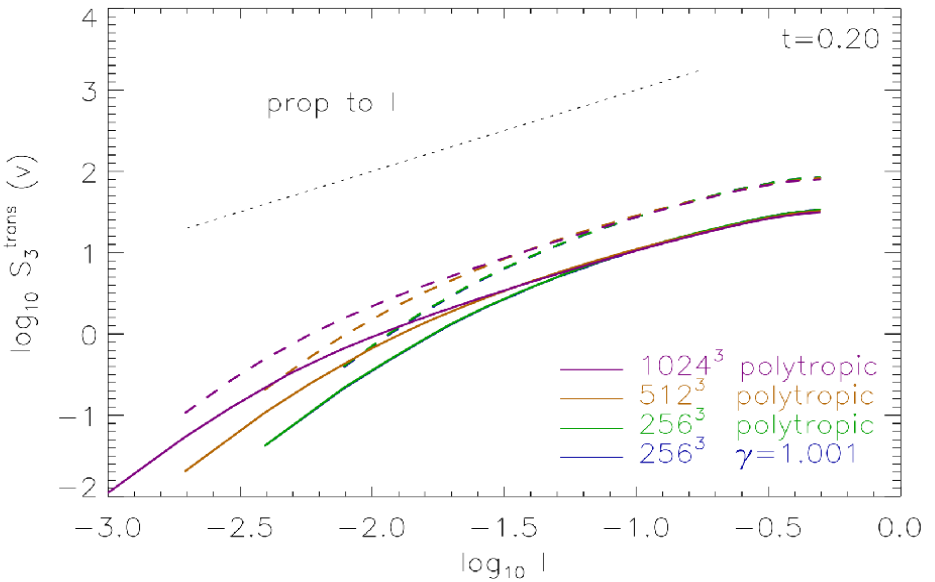
FLASH results – resolution study structure functions

t = 0.20

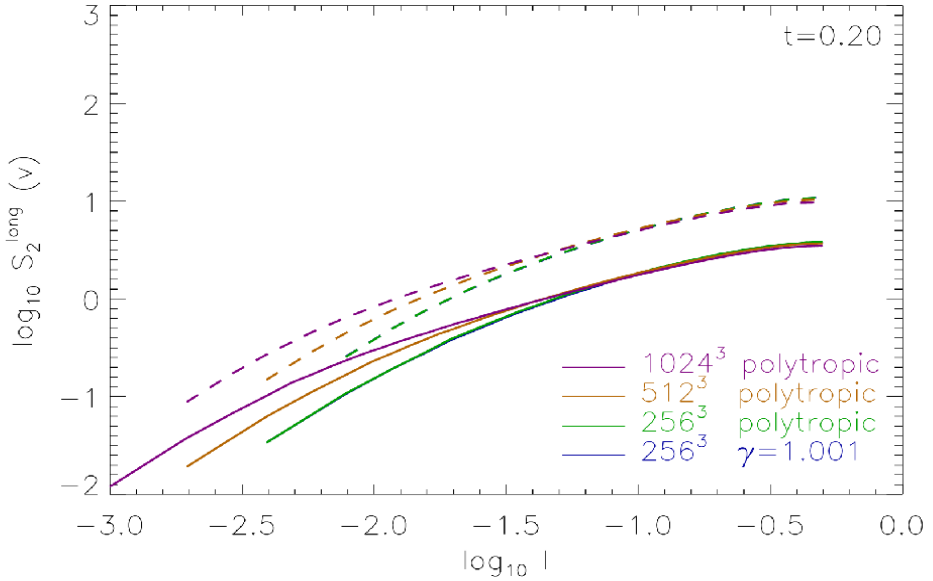
2nd order transversal



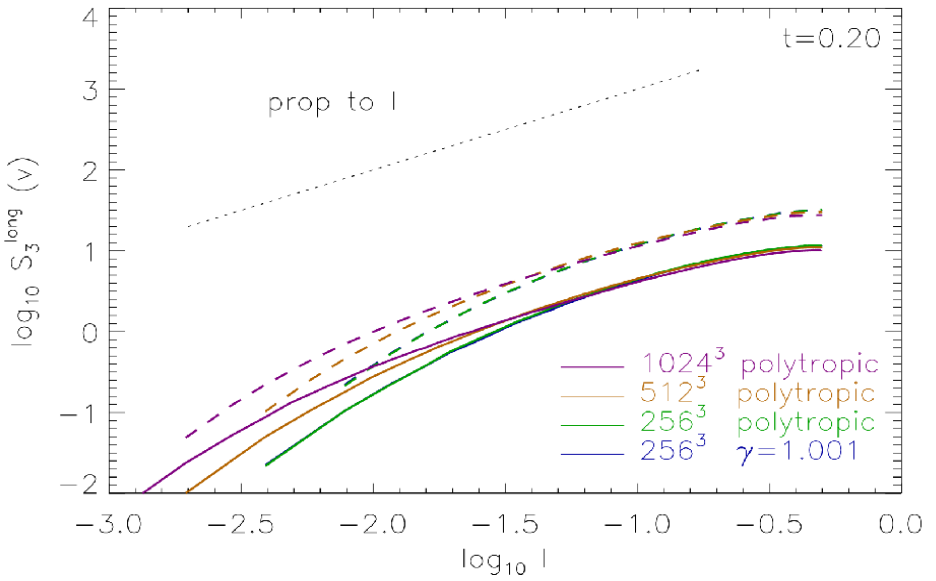
3rd order transversal



2nd order longitudinal

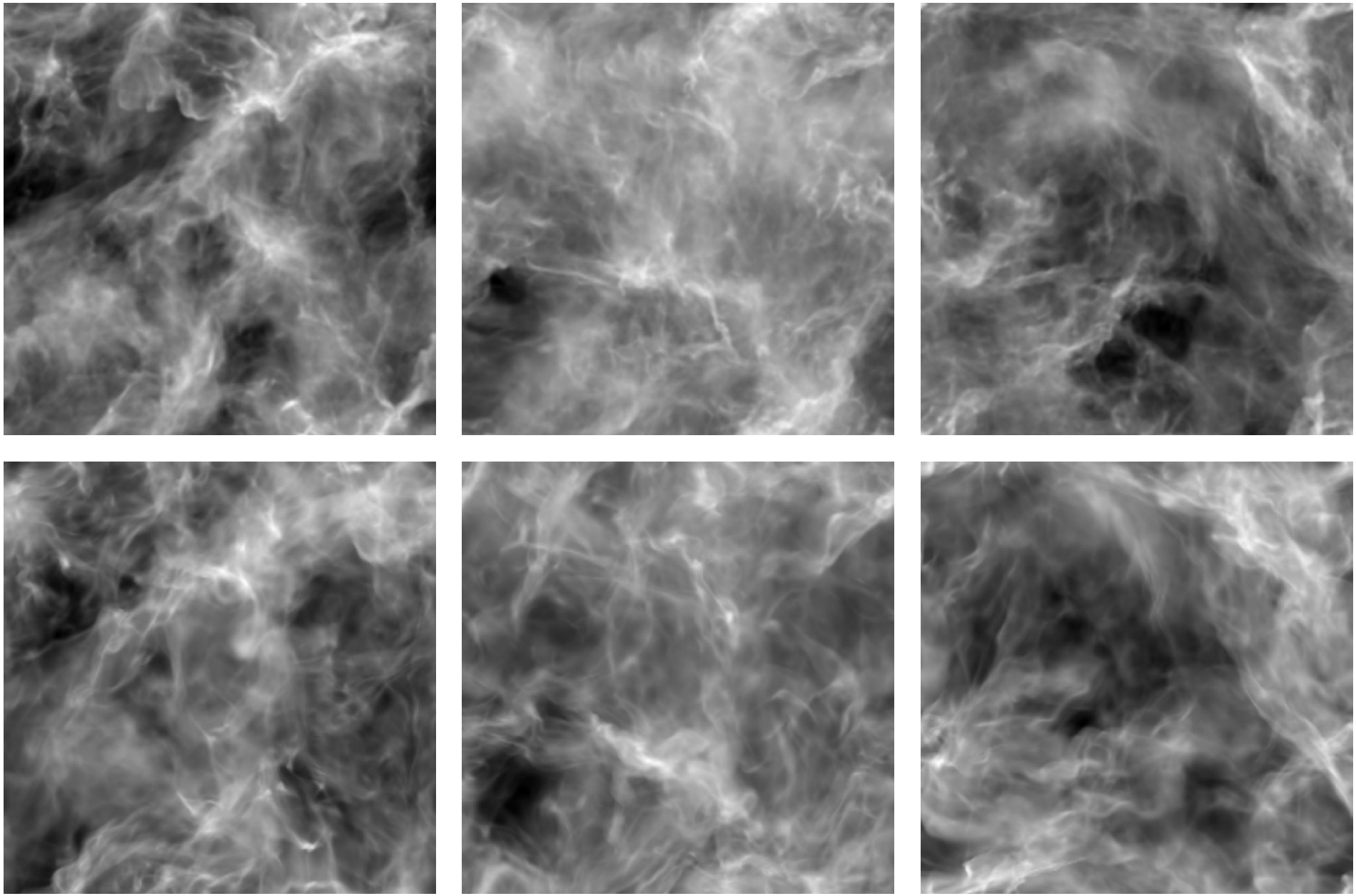


3rd order longitudinal

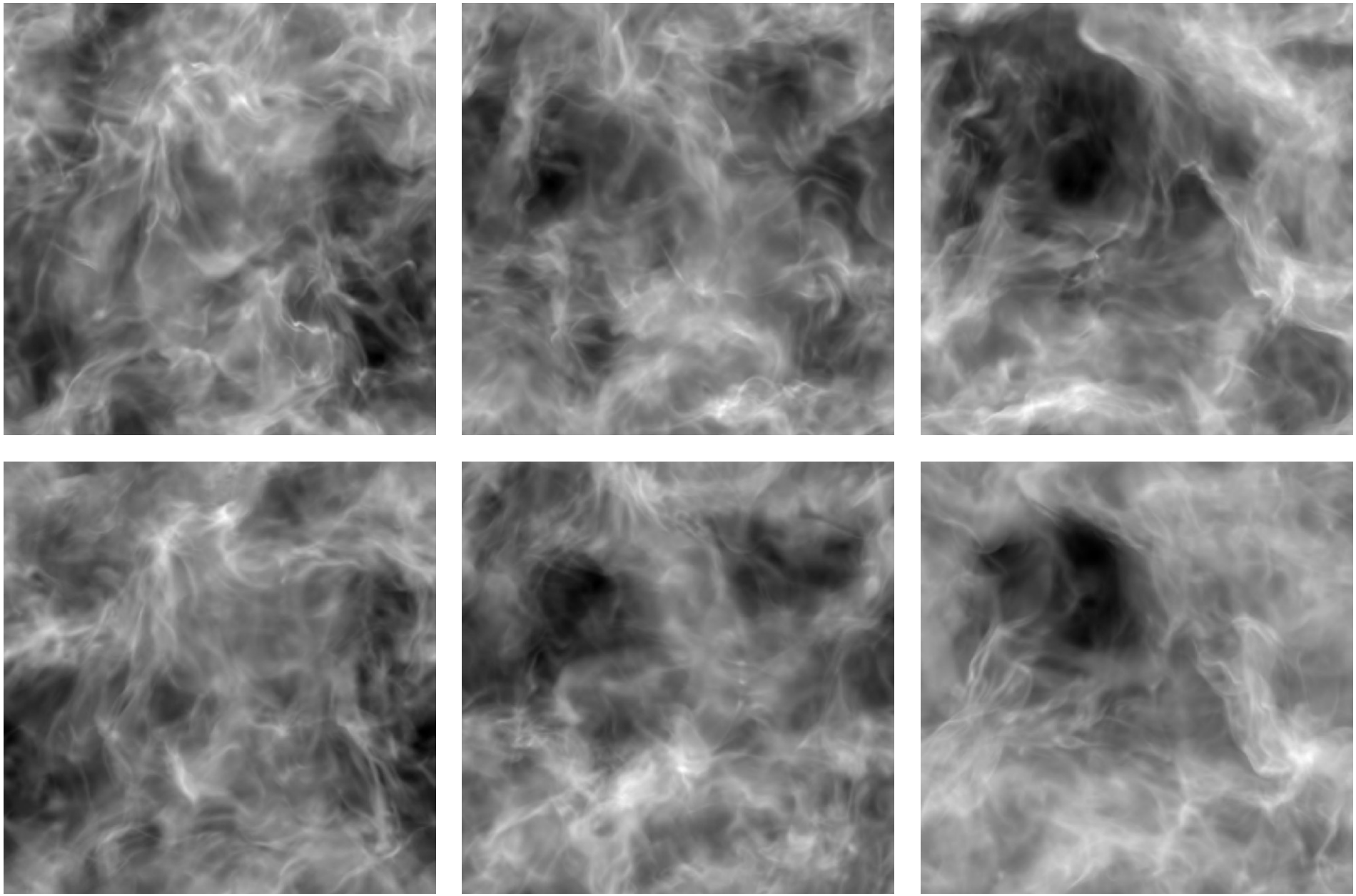


MHD 256^3
with proper
isothermal equation of state

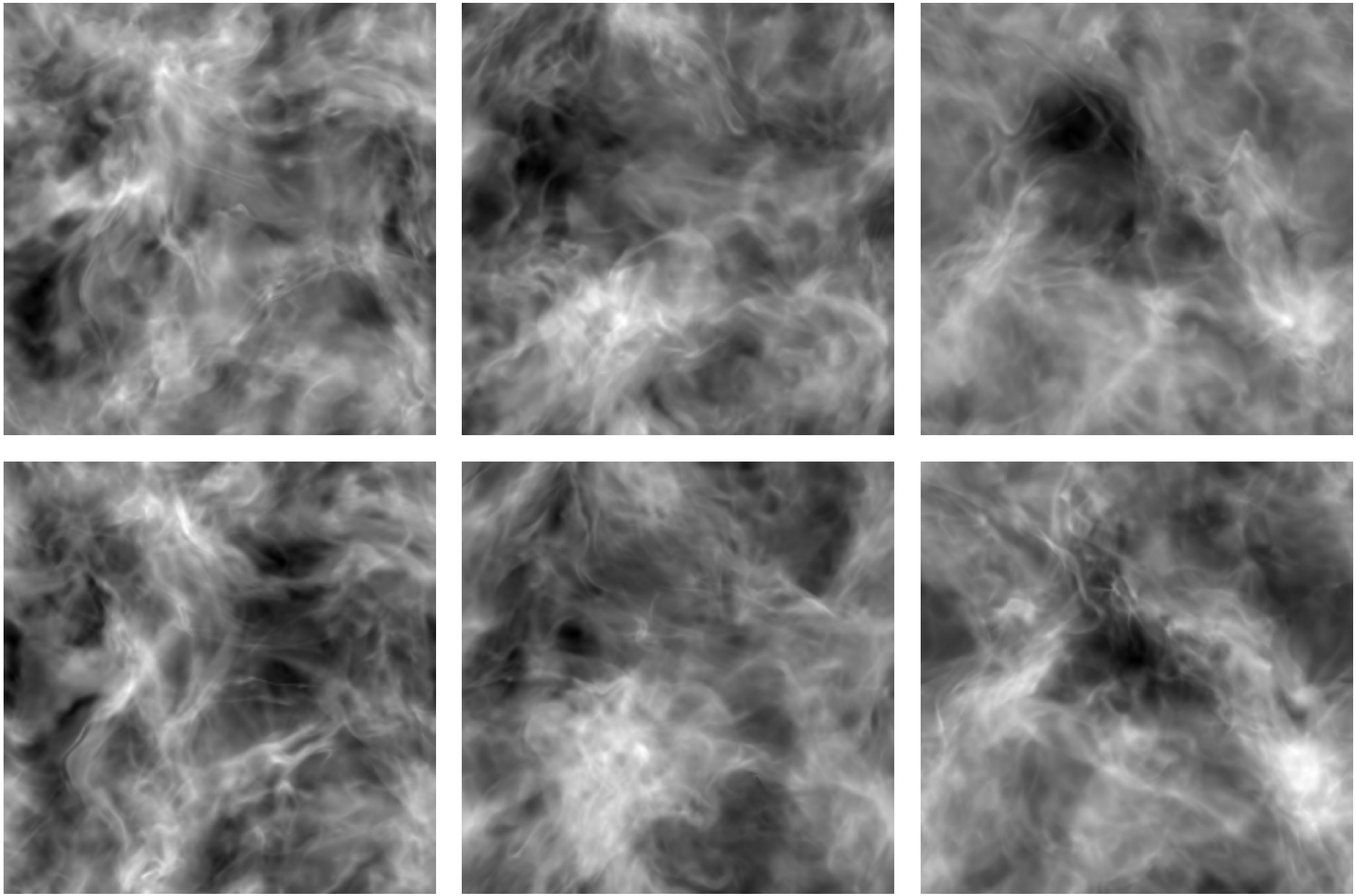
FLASH results – MHD 256^3 polytropic eos column density



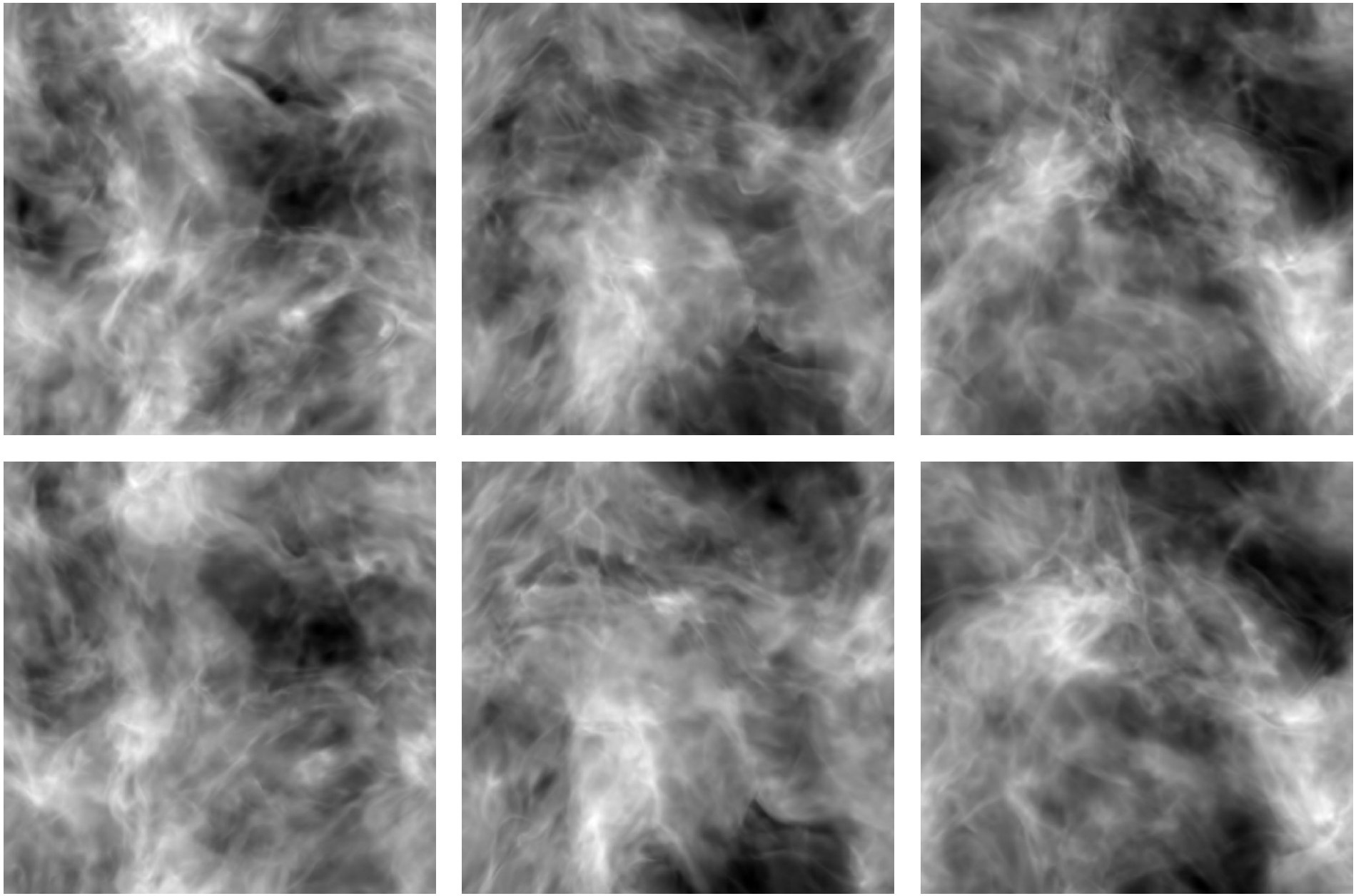
FLASH results – MHD 256^3 polytropic eos column density



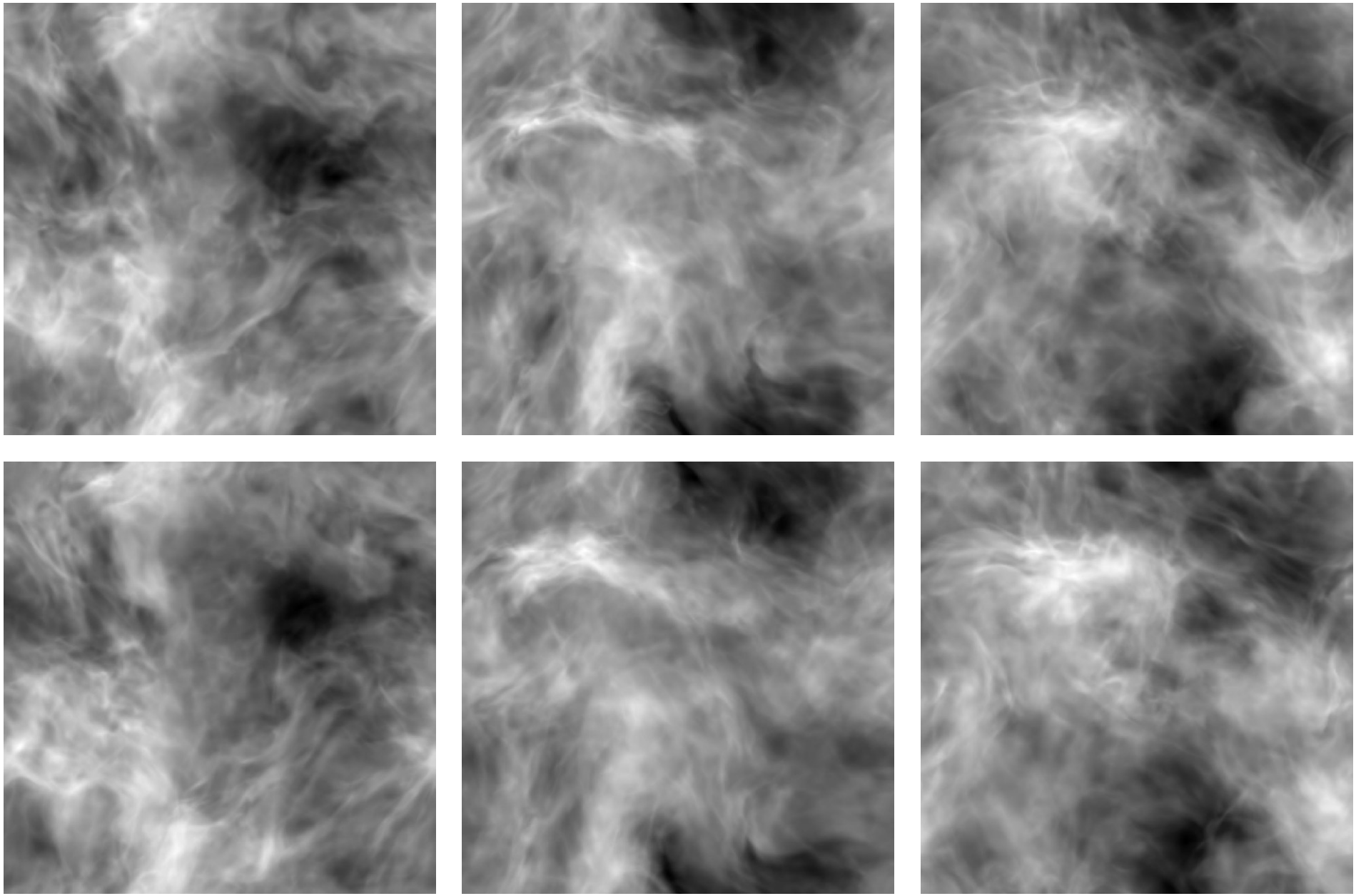
FLASH results – MHD 256^3 polytropic eos column density



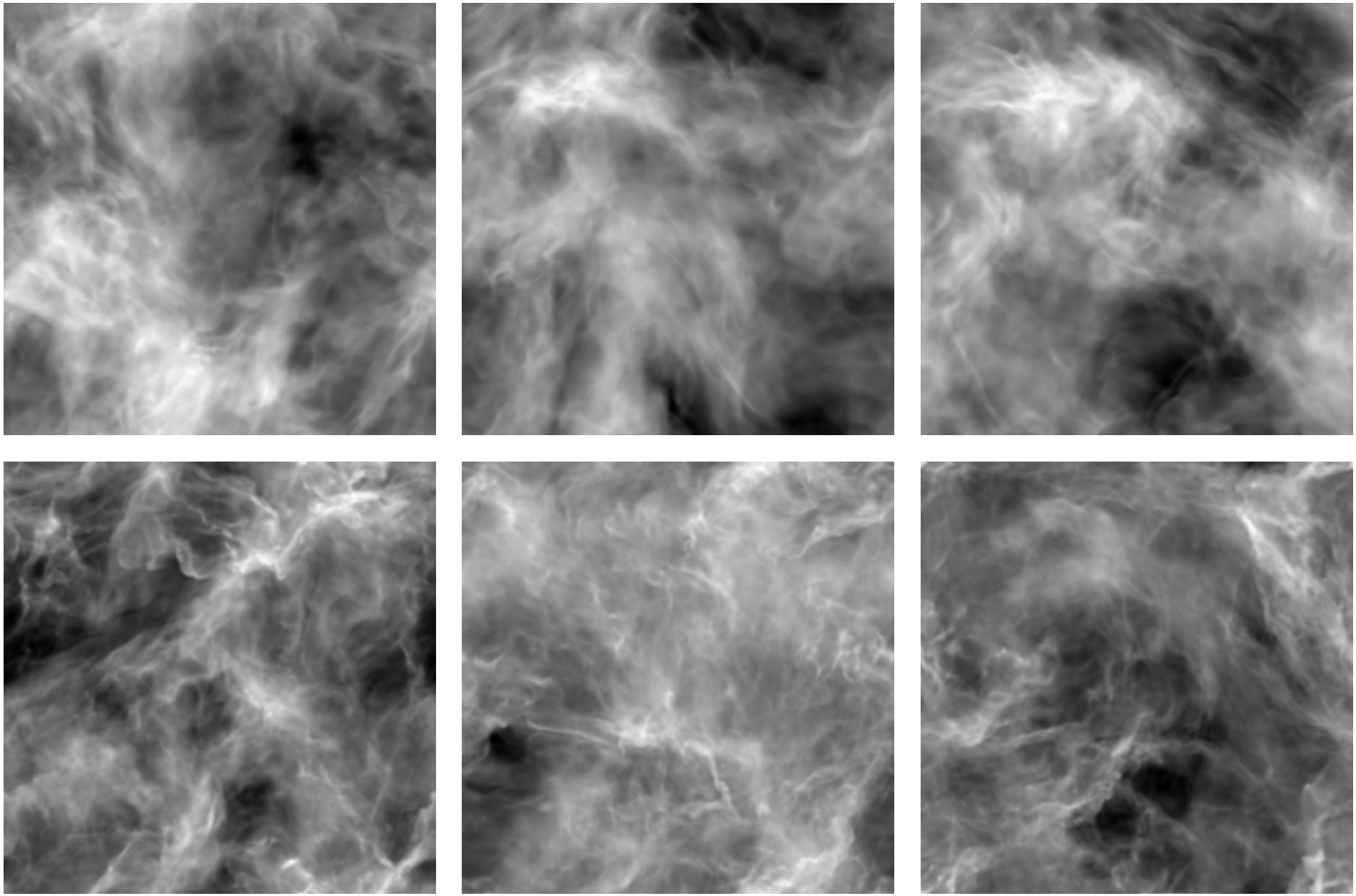
FLASH results – MHD 256^3 polytropic eos column density



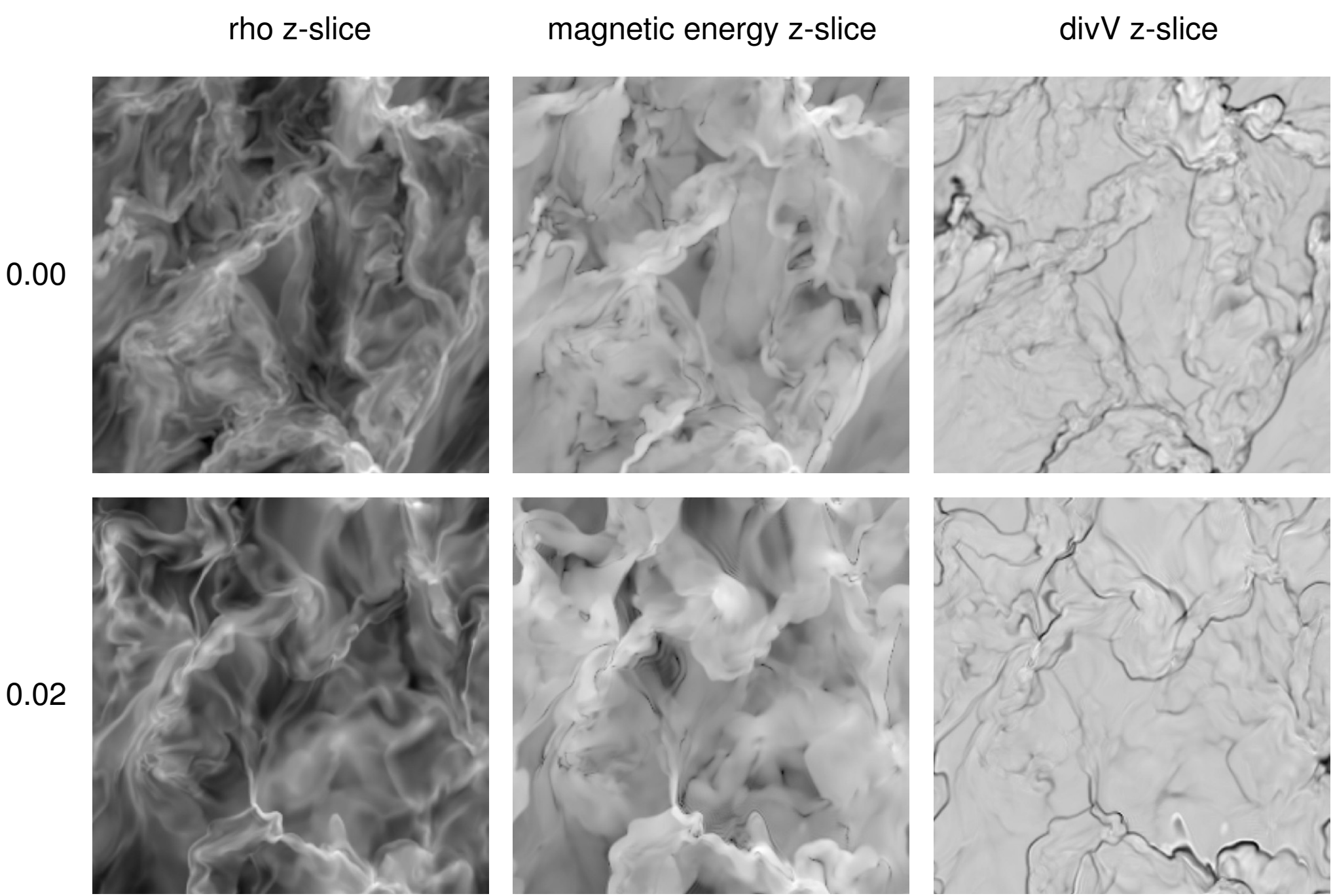
FLASH results – MHD 256^3 polytropic eos column density



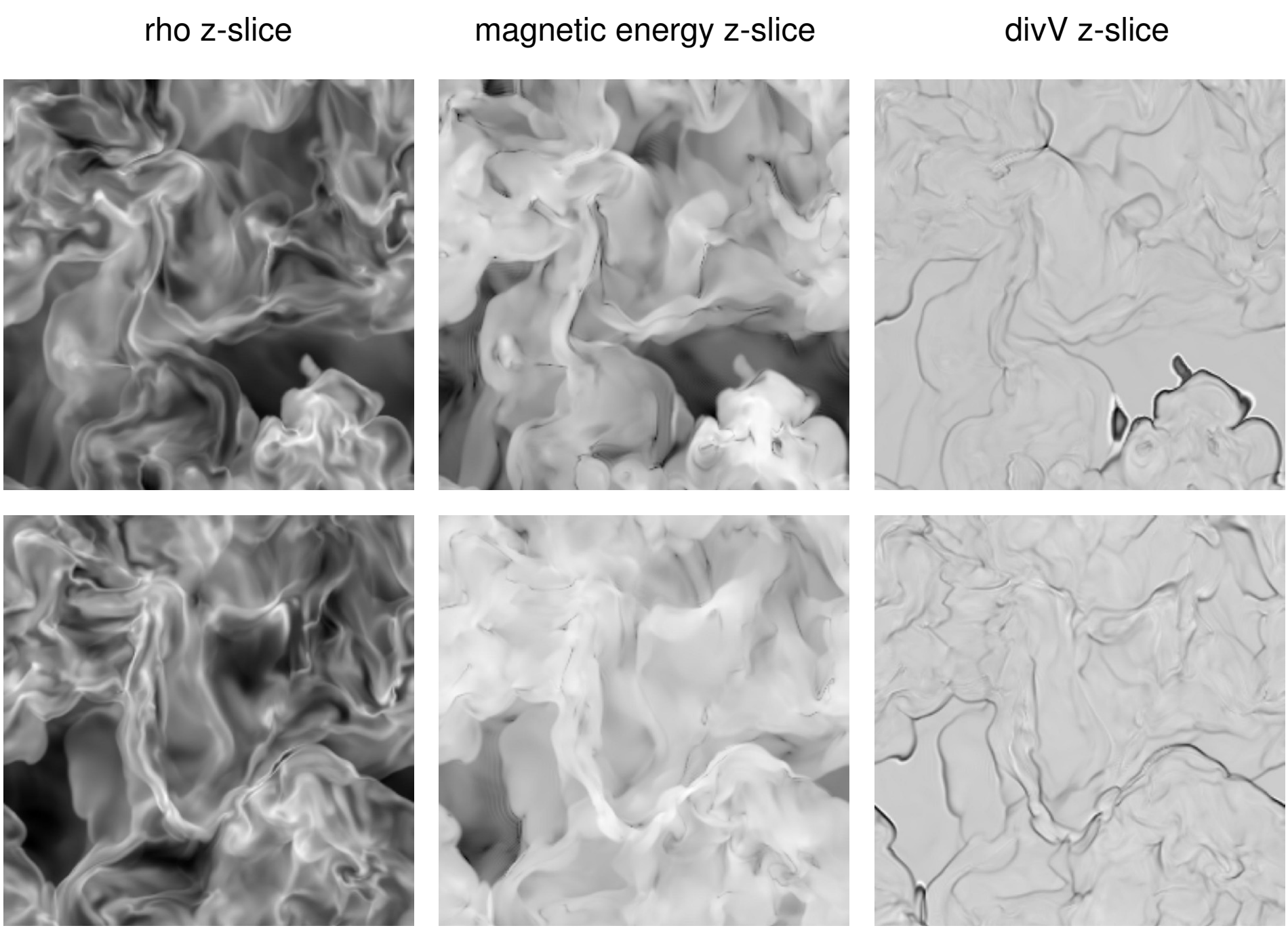
FLASH results – MHD 256^3 polytropic eos column density



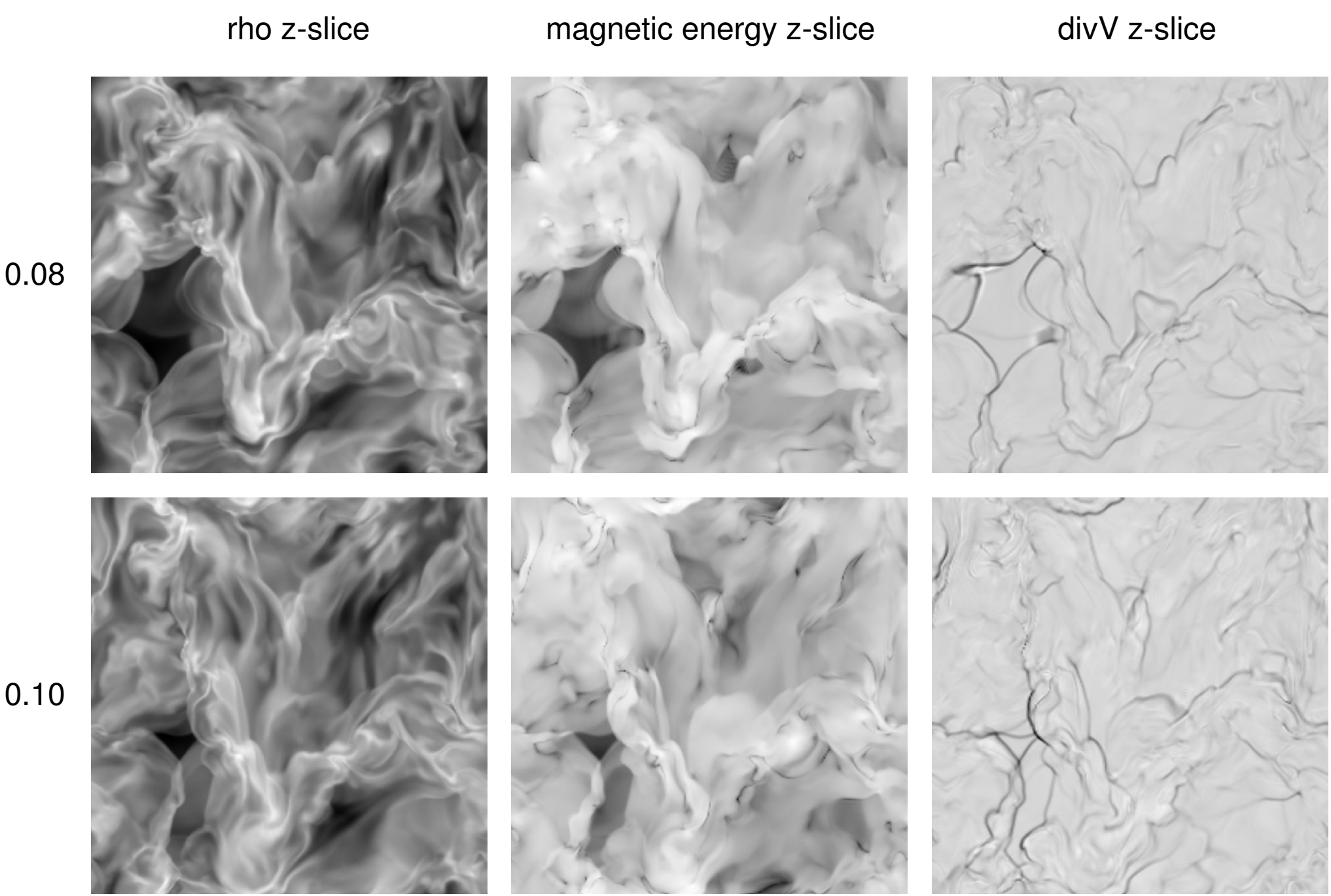
FLASH results – MHD 256^3 polytropic eos rho z-slice, Be-slice, divV z-slice



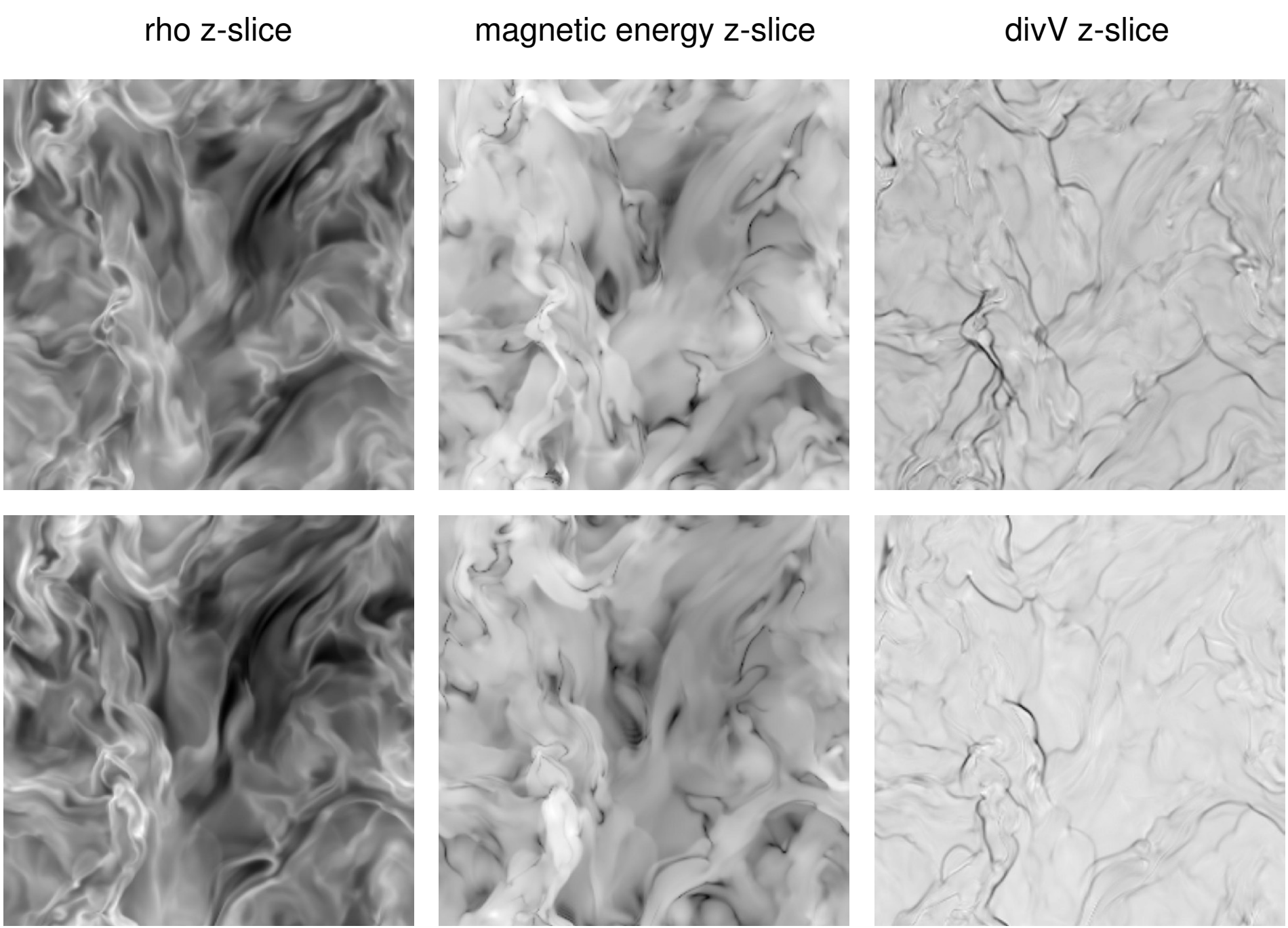
FLASH results – MHD 256^3 polytropic eos rho z-slice, Be-slice, divV z-slice



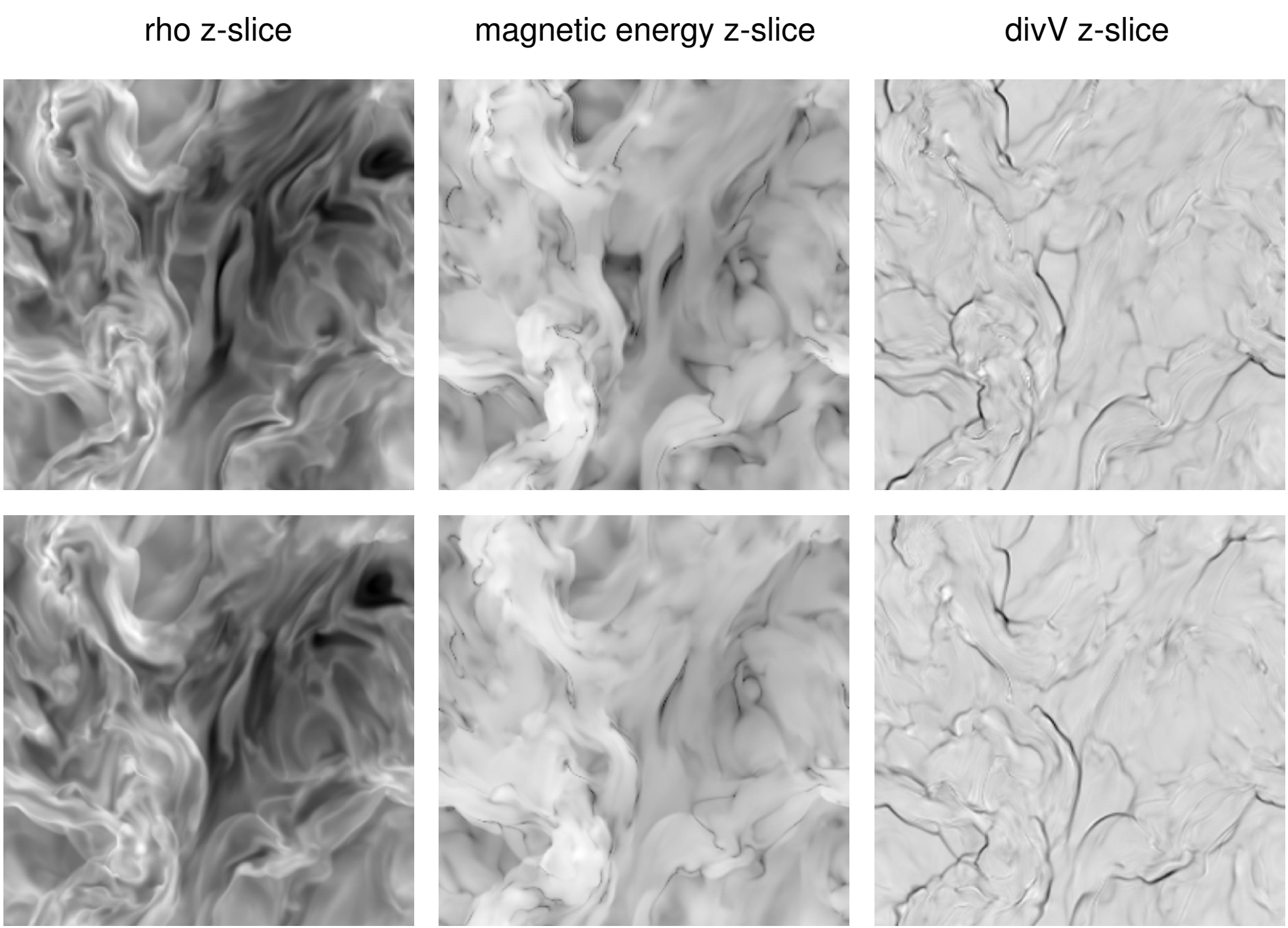
FLASH results – MHD 256^3 polytropic eos rho z-slice, Be-slice, divV z-slice



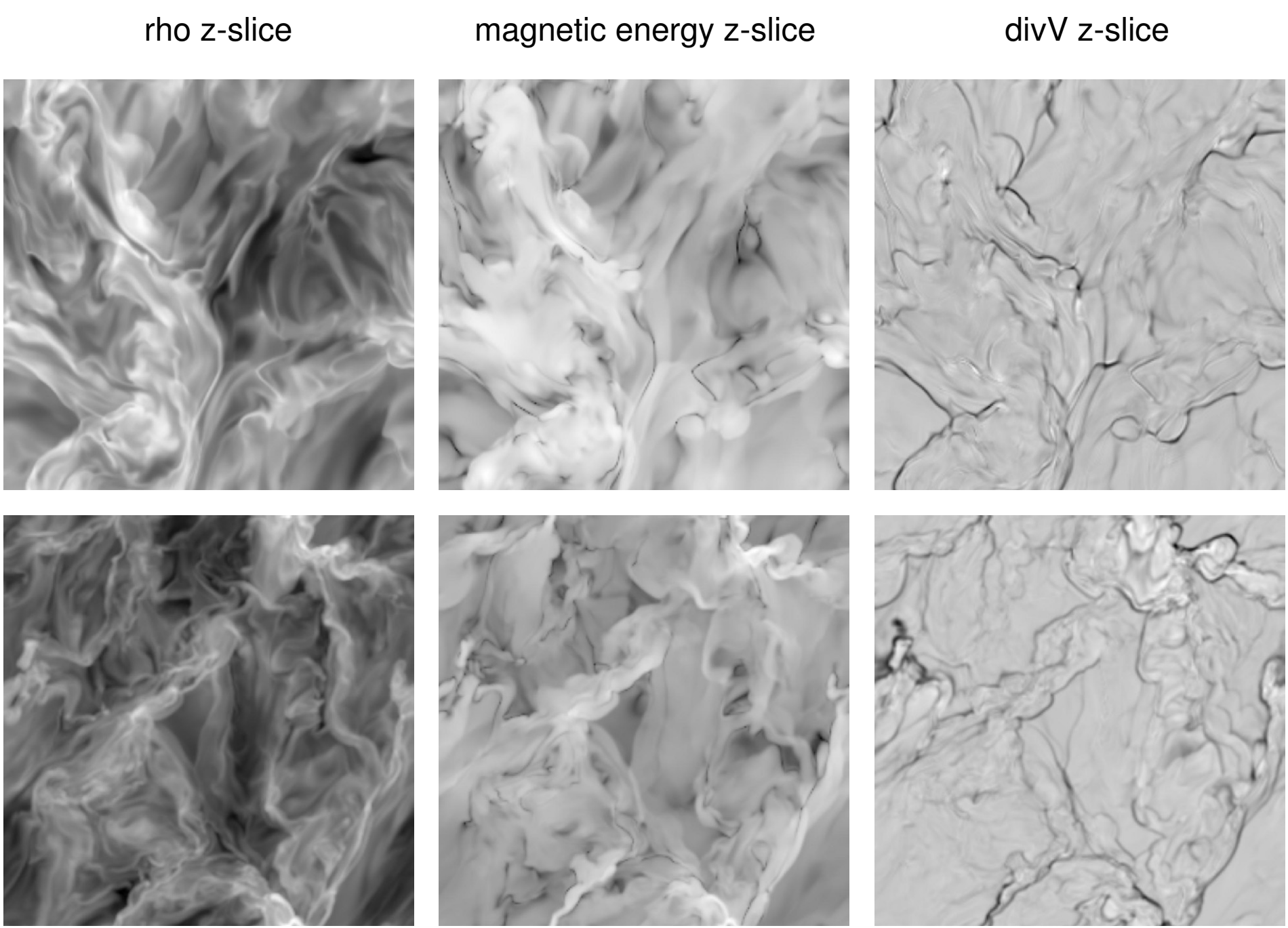
FLASH results – MHD 256^3 polytropic eos rho z-slice, Be-slice, divV z-slice



FLASH results – MHD 256^3 polytropic eos rho z-slice, Be-slice, divV z-slice

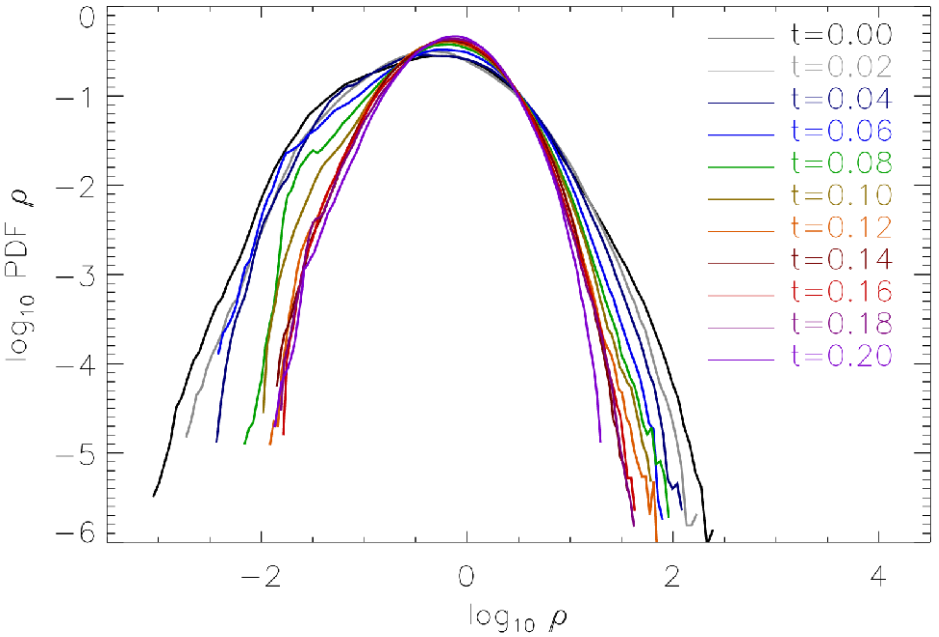


FLASH results – MHD 256^3 polytropic eos rho z-slice, Be-slice, divV z-slice

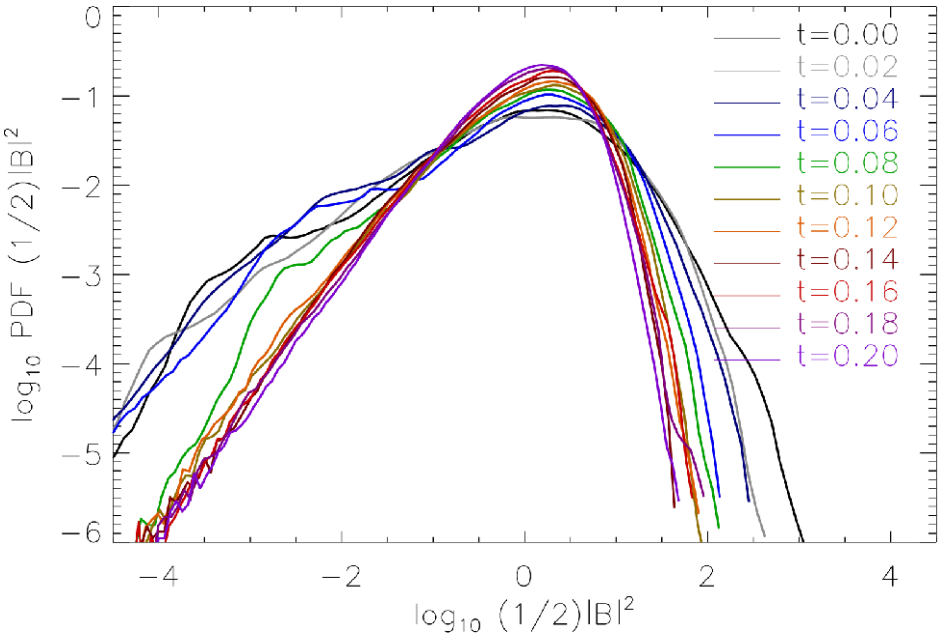


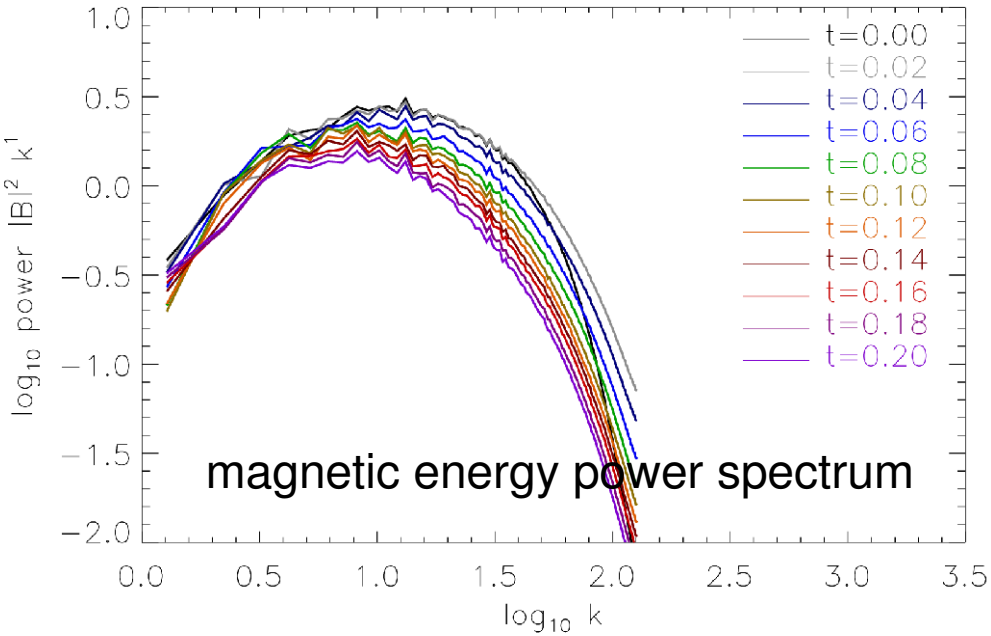
FLASH results – MHD 256^3 polytropic eos PDFs + magnetic spectrum

density PDF

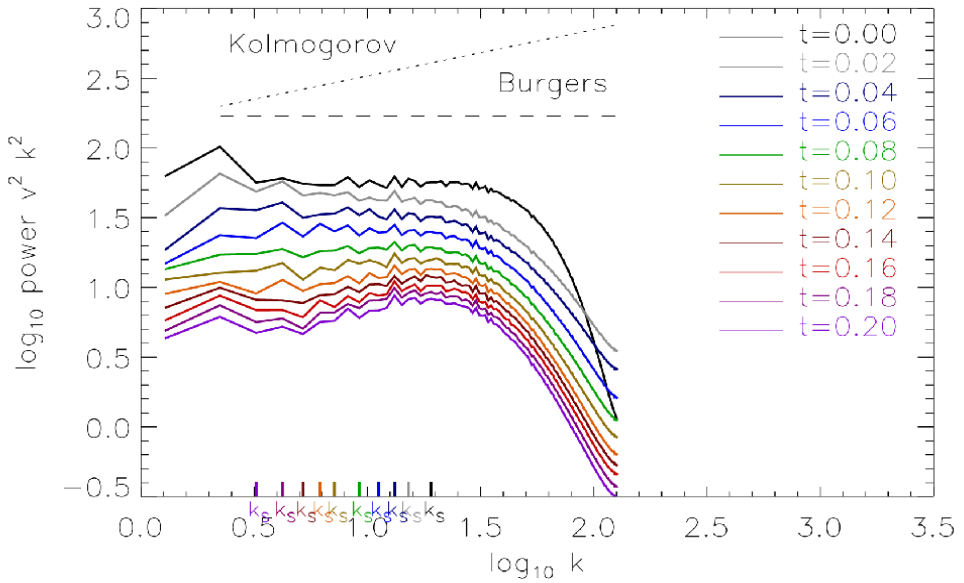


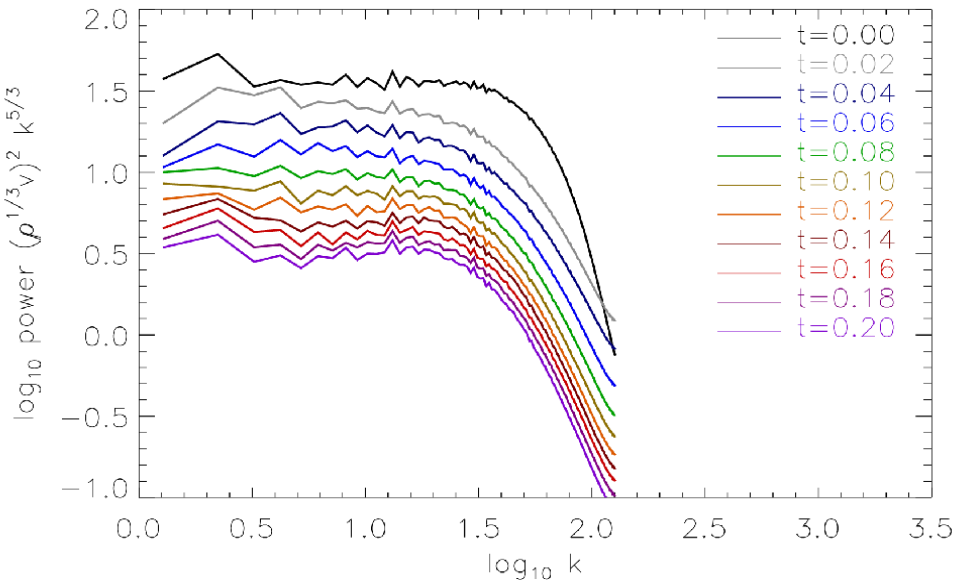
magnetic energy PDF

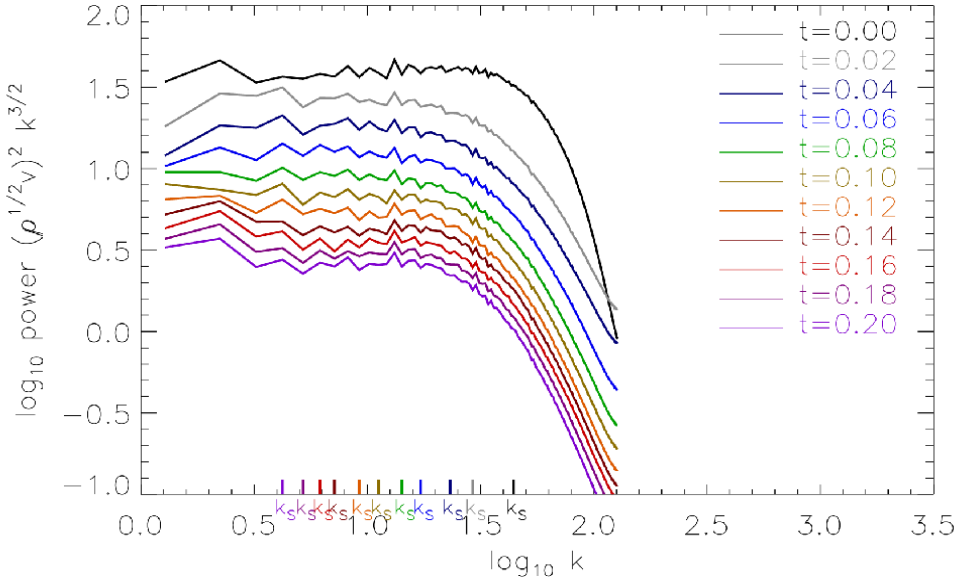


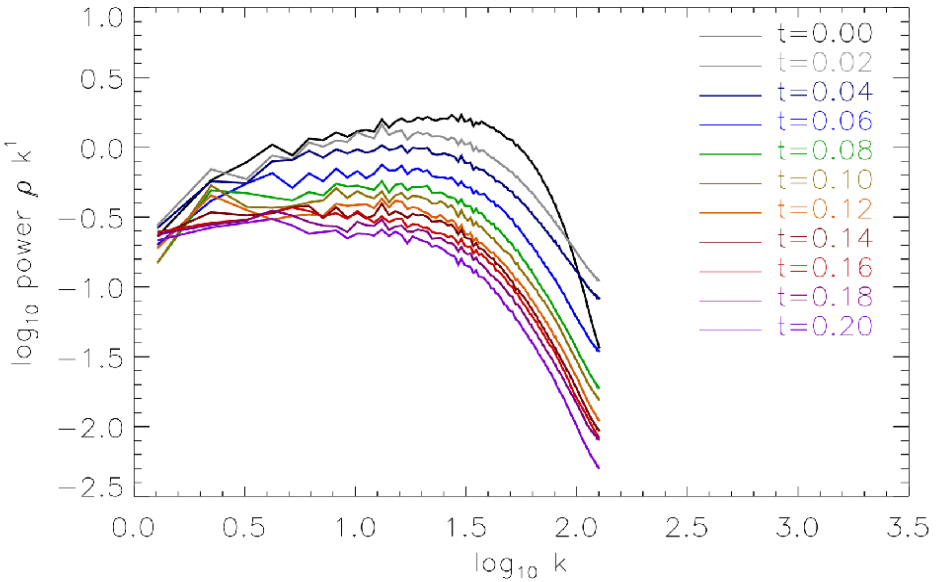


FLASH results – MHD 256^3 polytropic eos power spectra



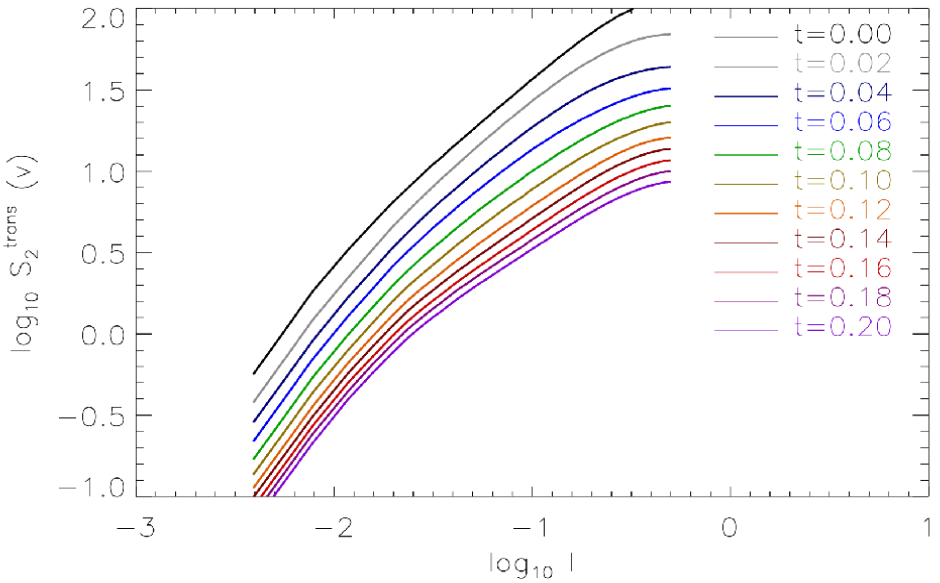




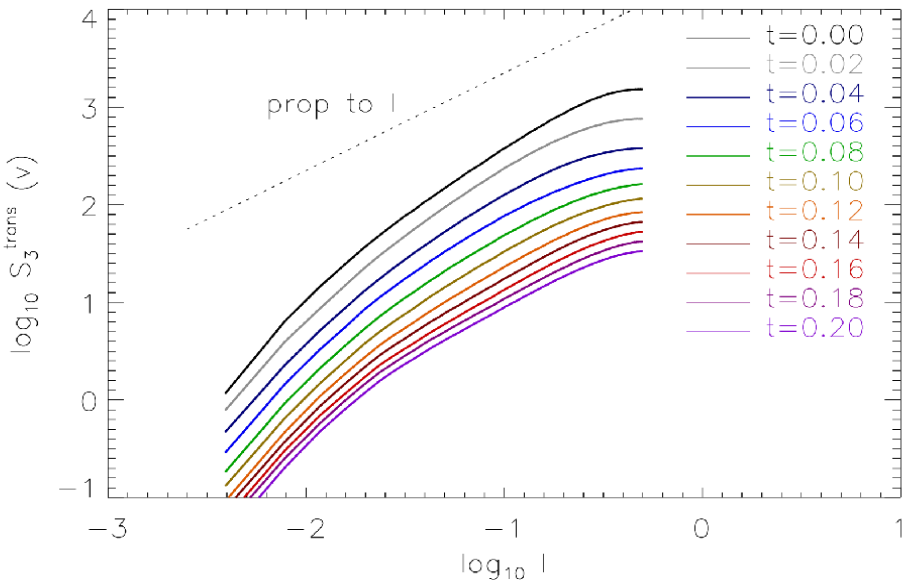


FLASH results – MHD 256^3 polytropic eos structure functions

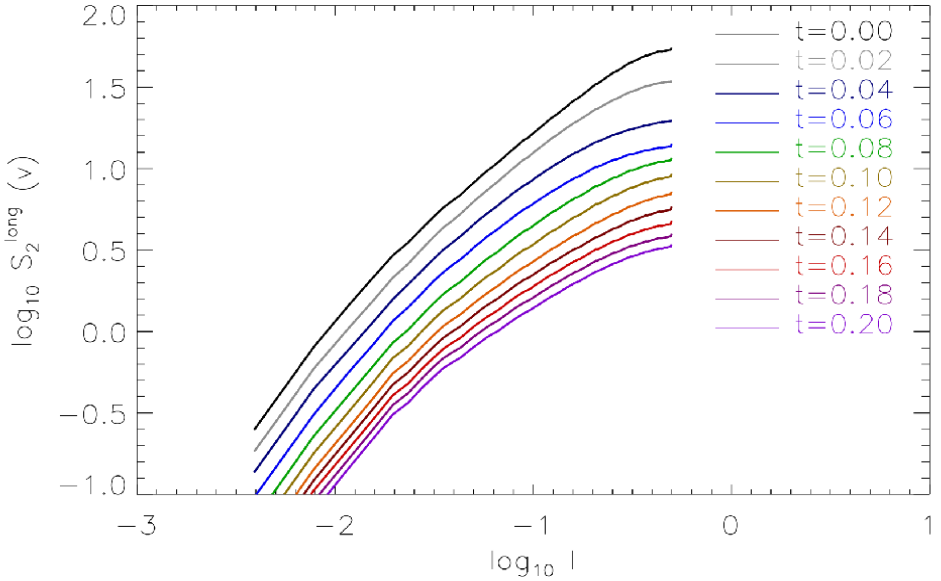
2nd order transversal



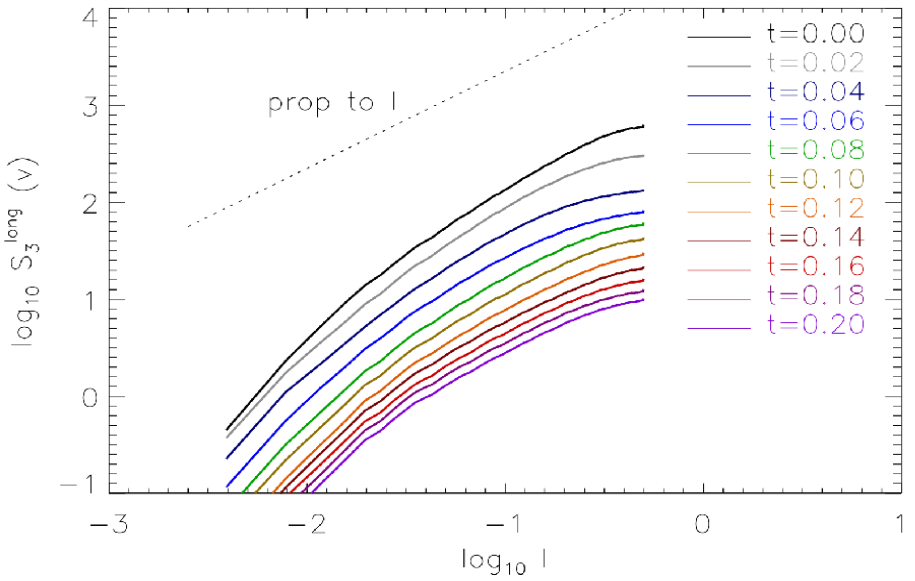
3rd order transversal



2nd order longitudinal

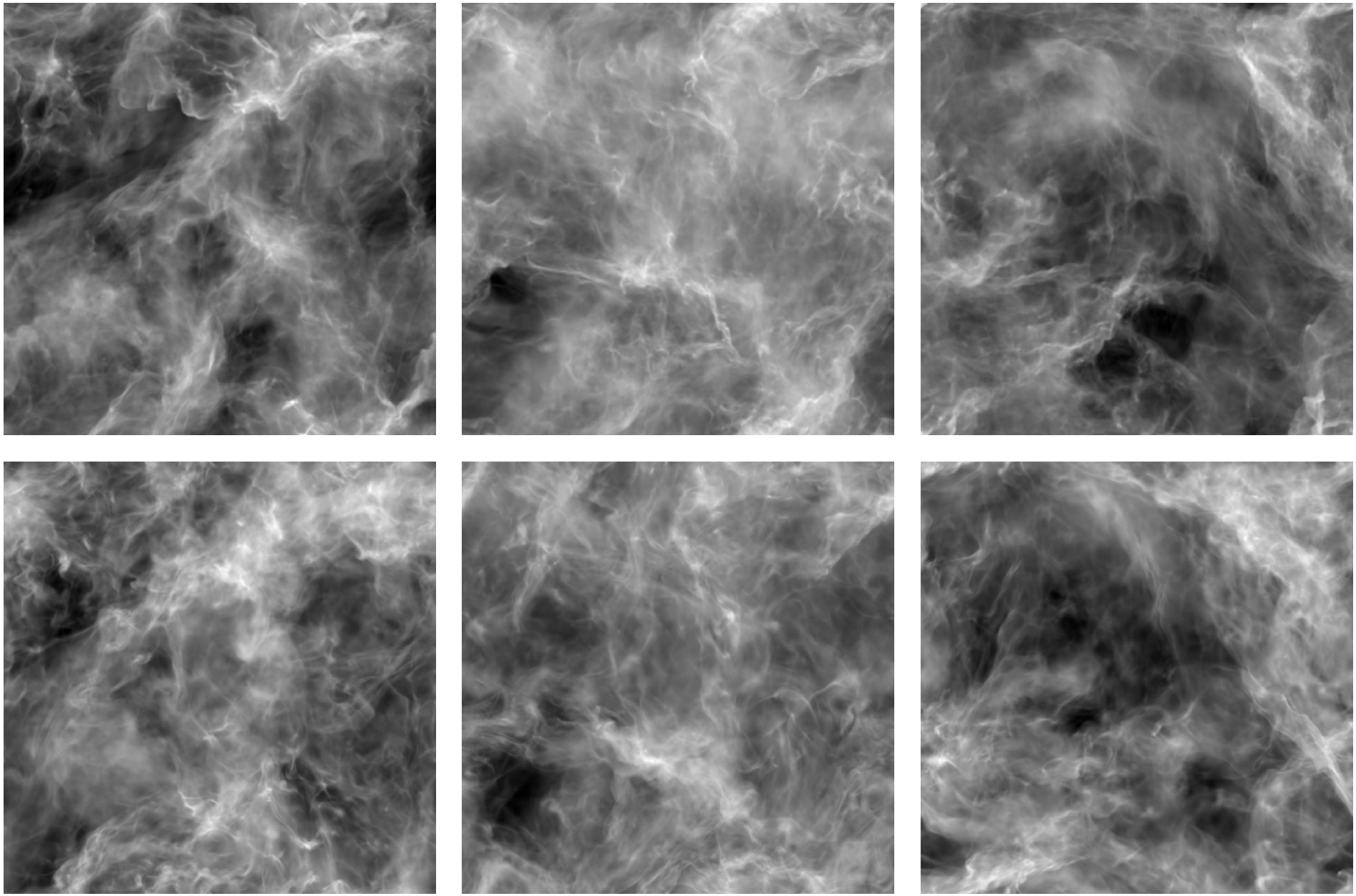


3rd order longitudinal

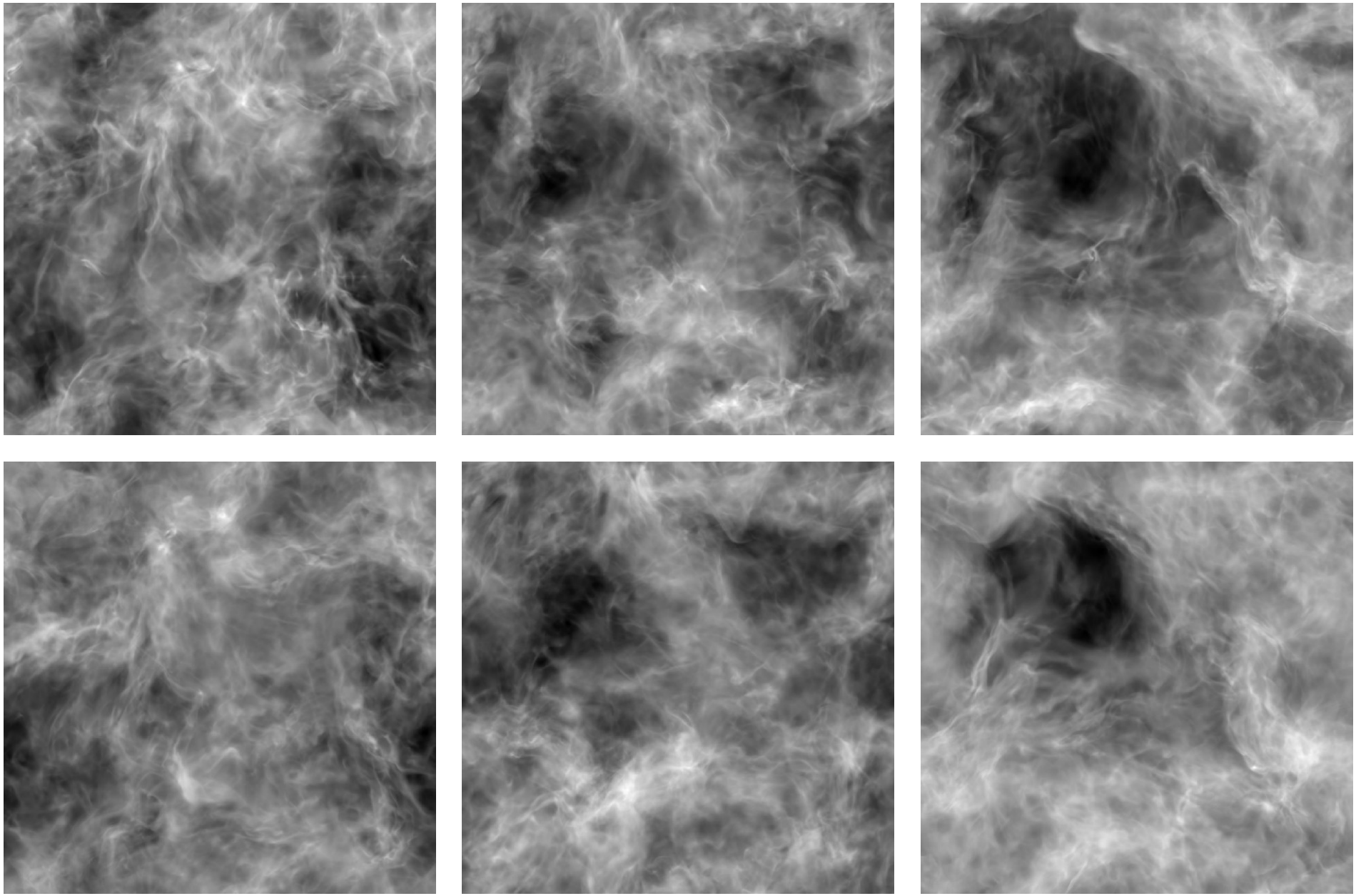


MHD 512^3
with proper
isothermal equation of state

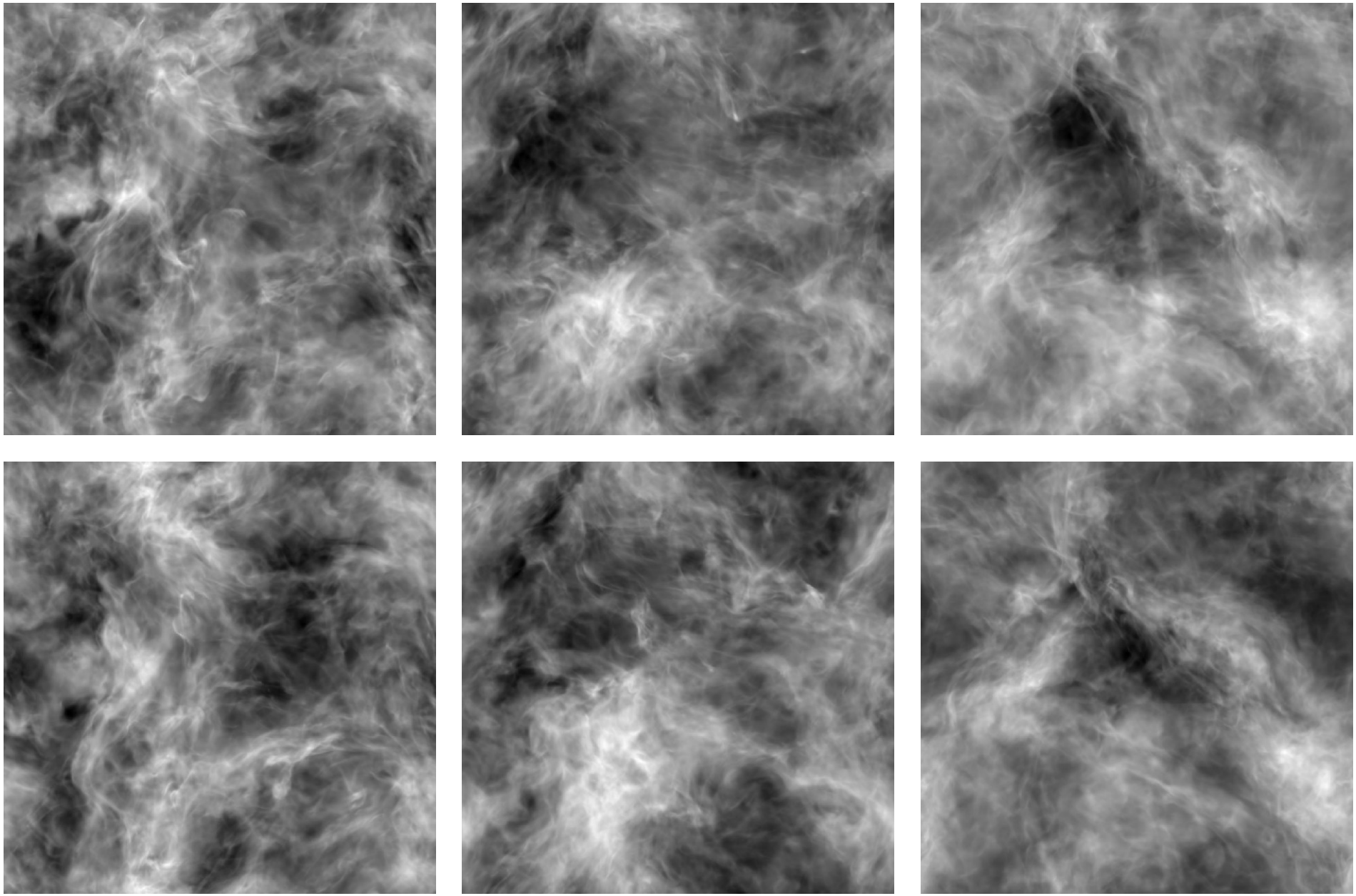
FLASH results – MHD 512^3 polytropic eos column density



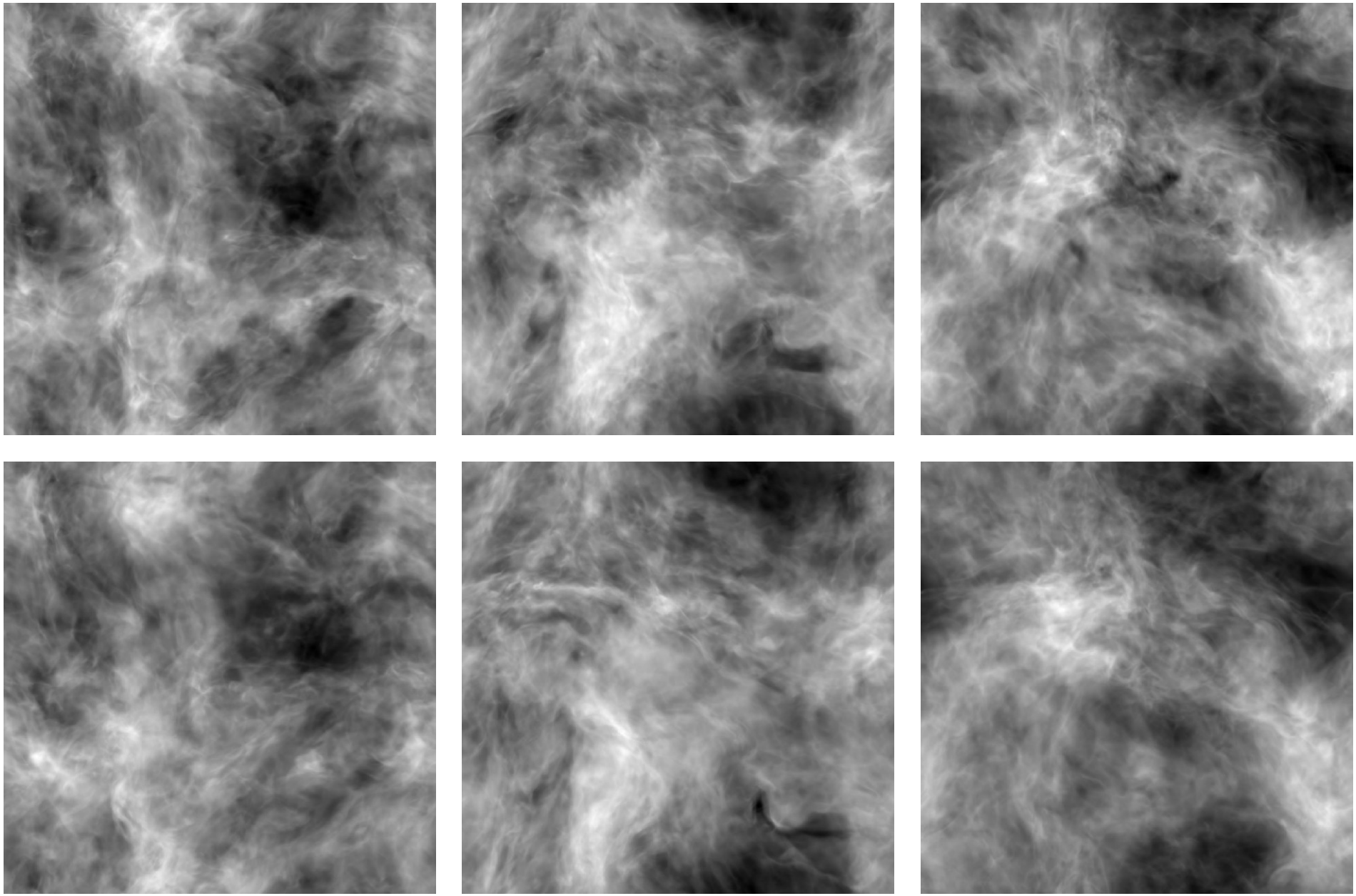
FLASH results – MHD 512^3 polytropic eos column density



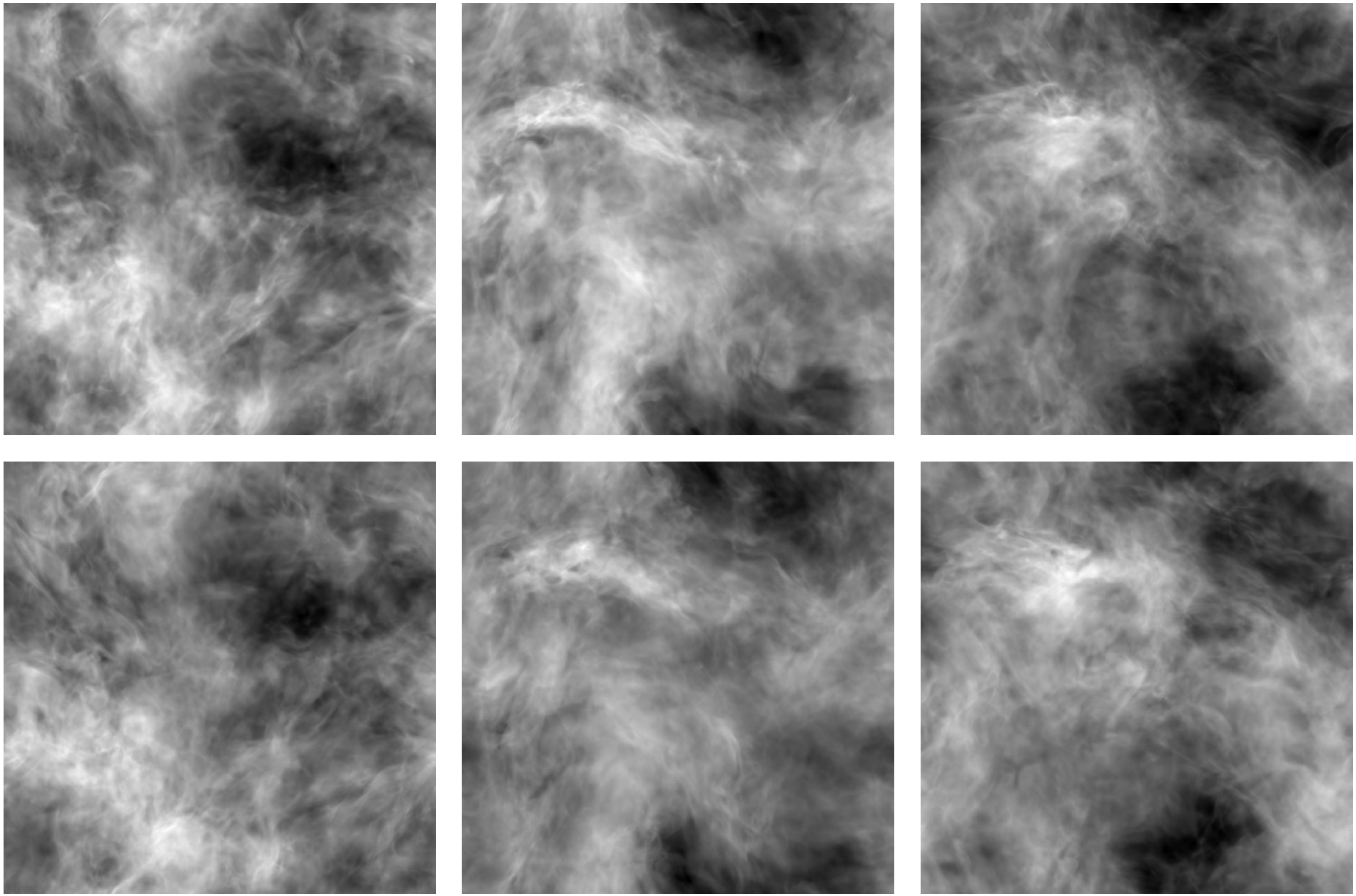
FLASH results – MHD 512^3 polytropic eos column density



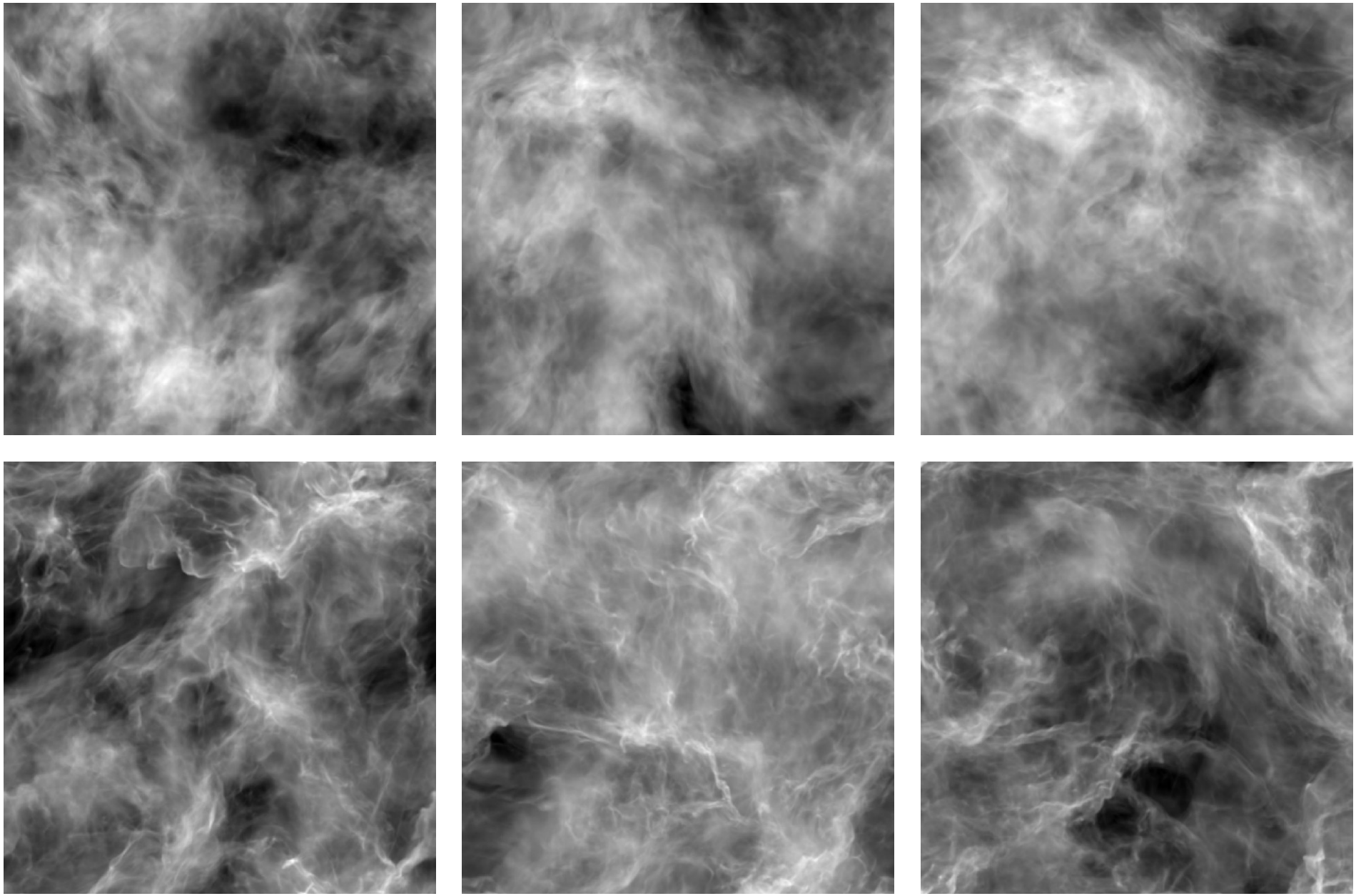
FLASH results – MHD 512^3 polytropic eos column density



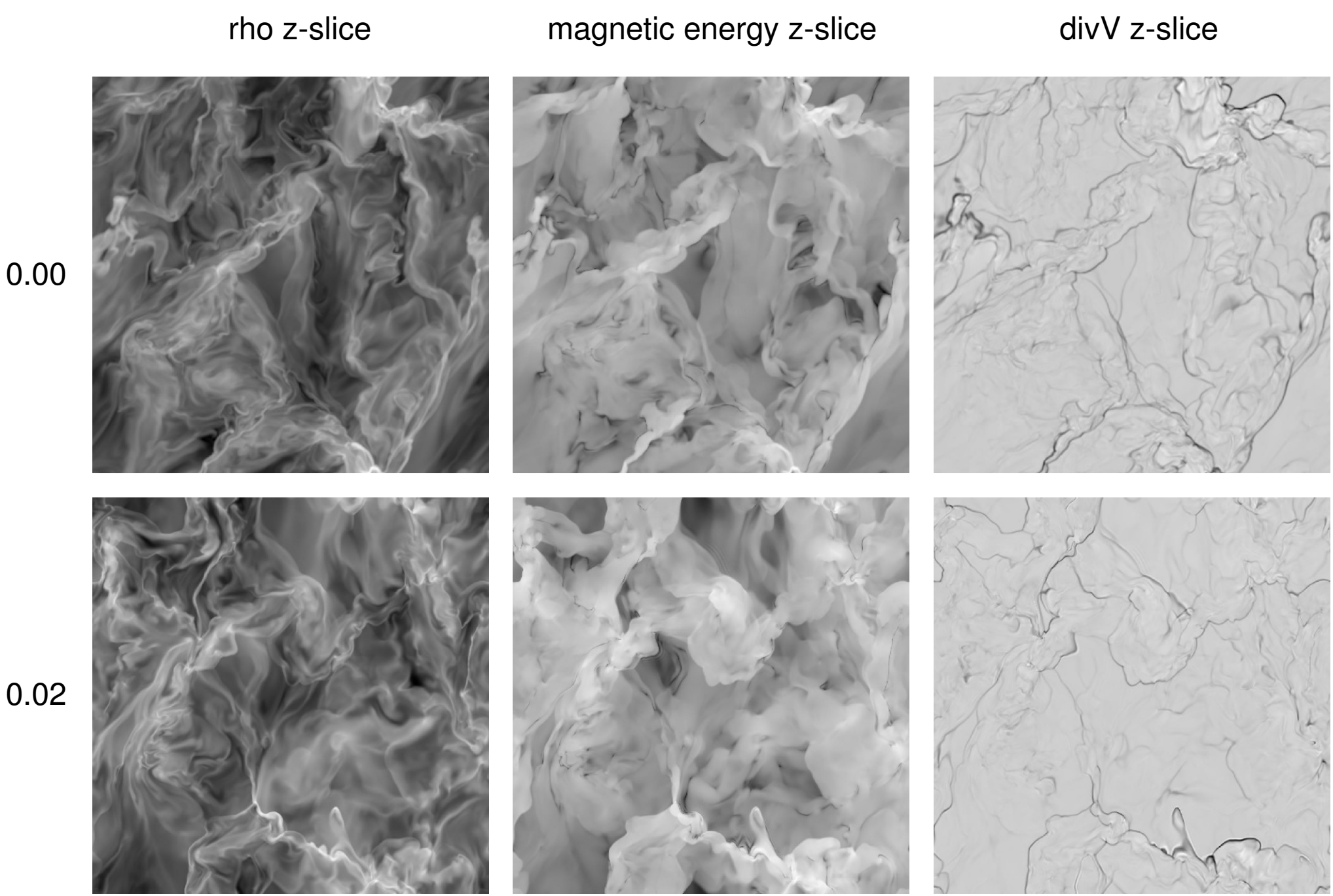
FLASH results – MHD 512^3 polytropic eos column density



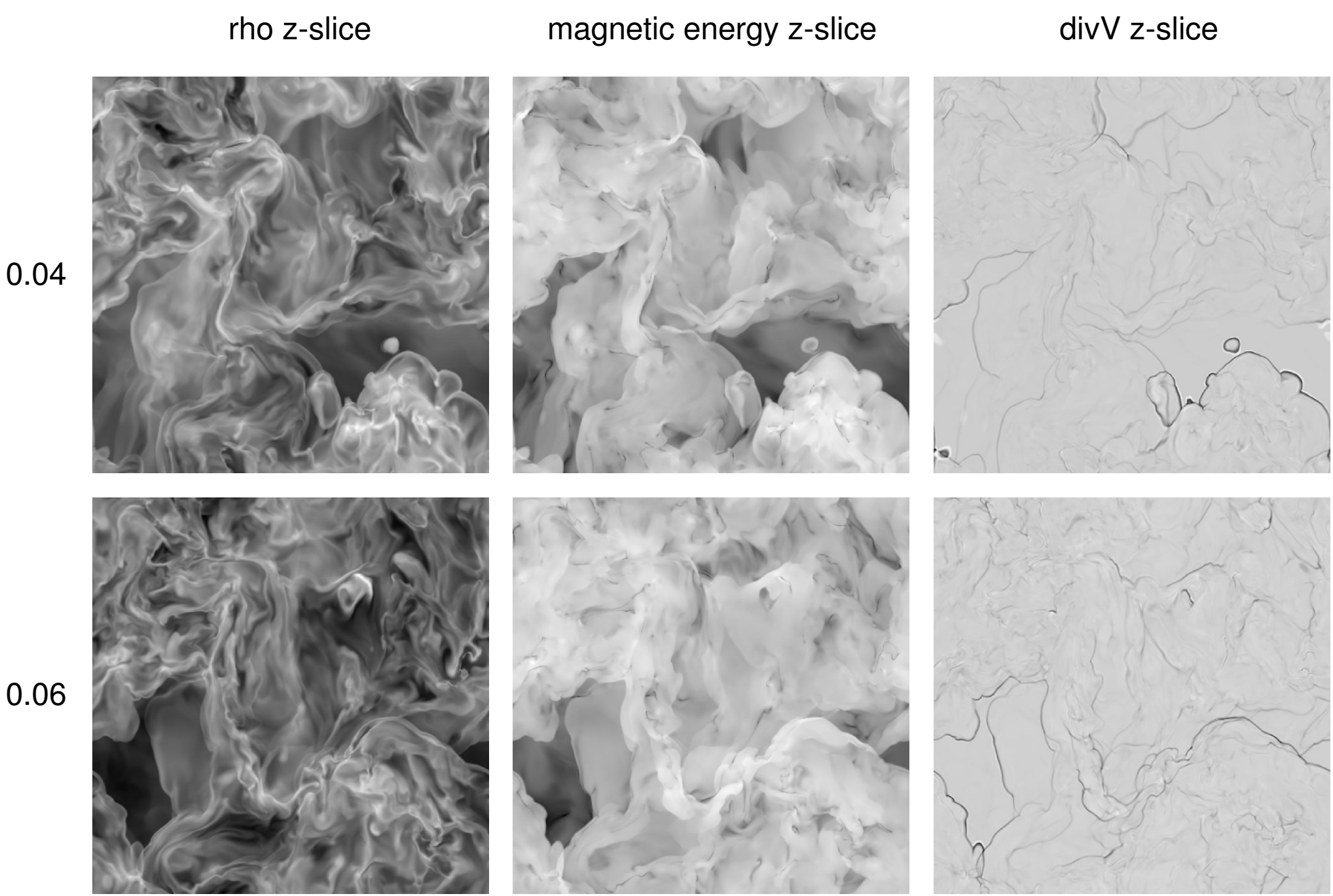
FLASH results – MHD 512^3 polytropic eos column density



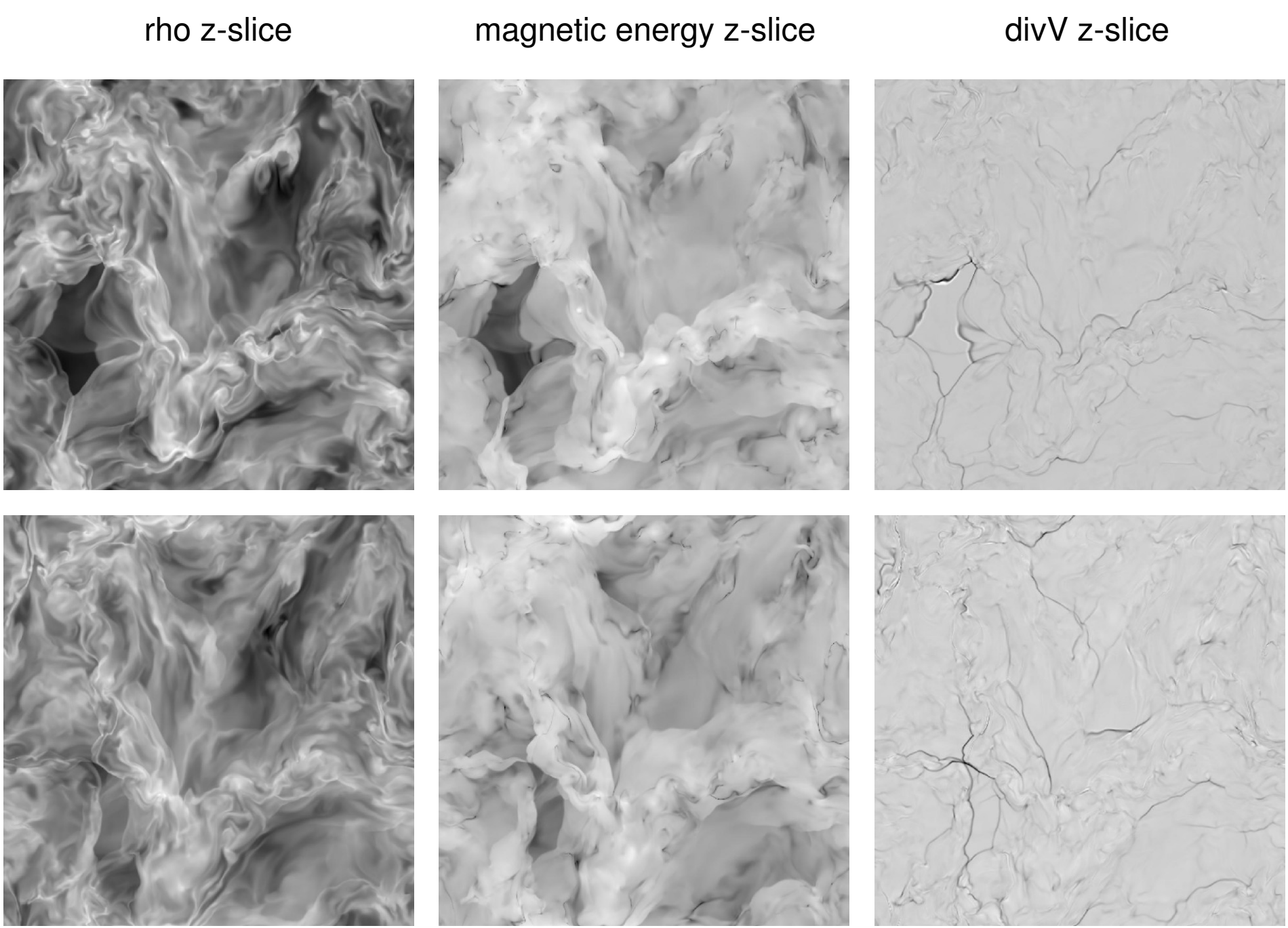
FLASH results – MHD 512^3 polytropic eos rho z-slice, Be-slice, divV z-slice



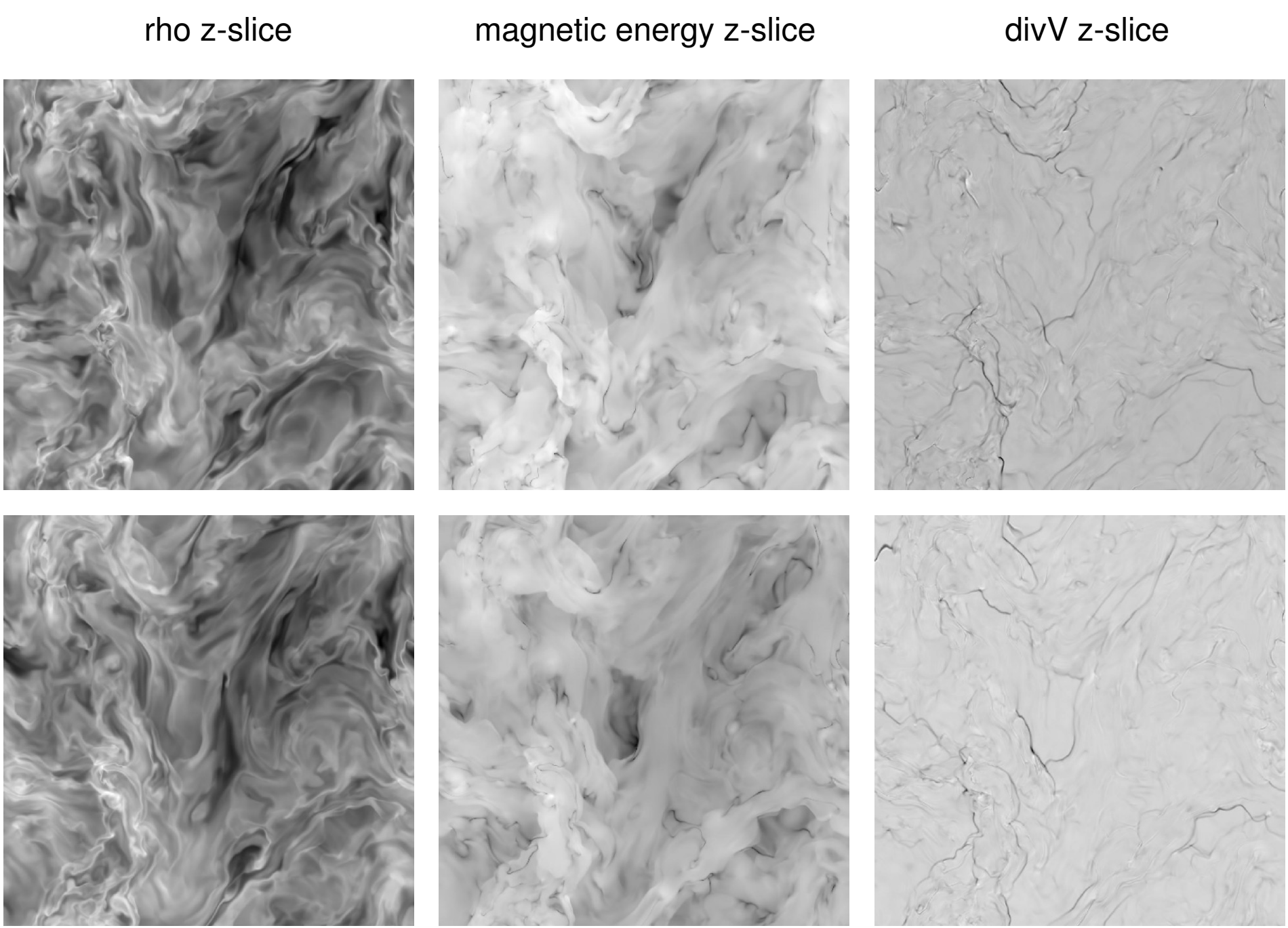
FLASH results – MHD 512^3 polytropic eos rho z-slice, Be-slice, divV z-slice



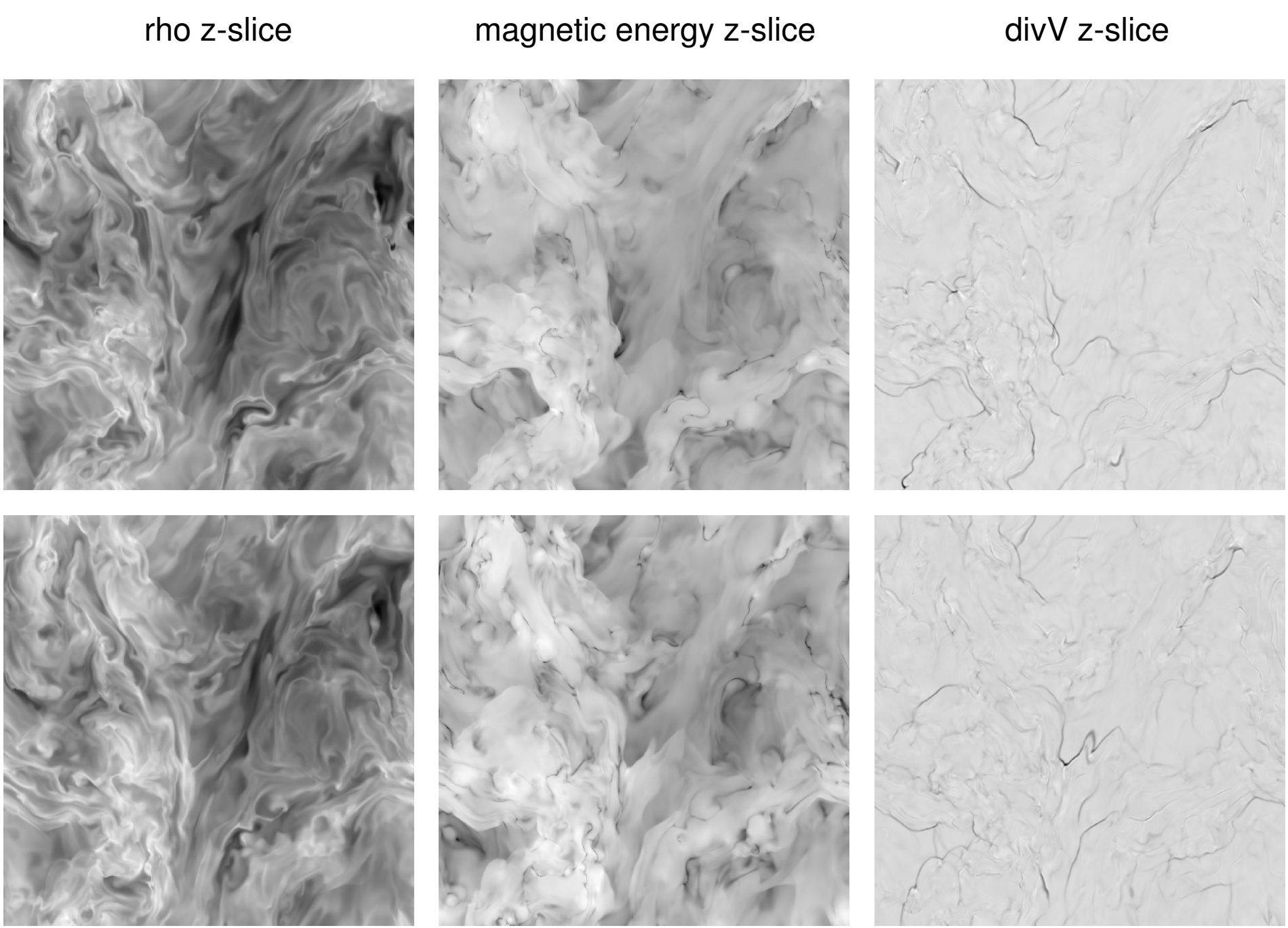
FLASH results – MHD 512^3 polytropic eos rho z-slice, Be-slice, divV z-slice



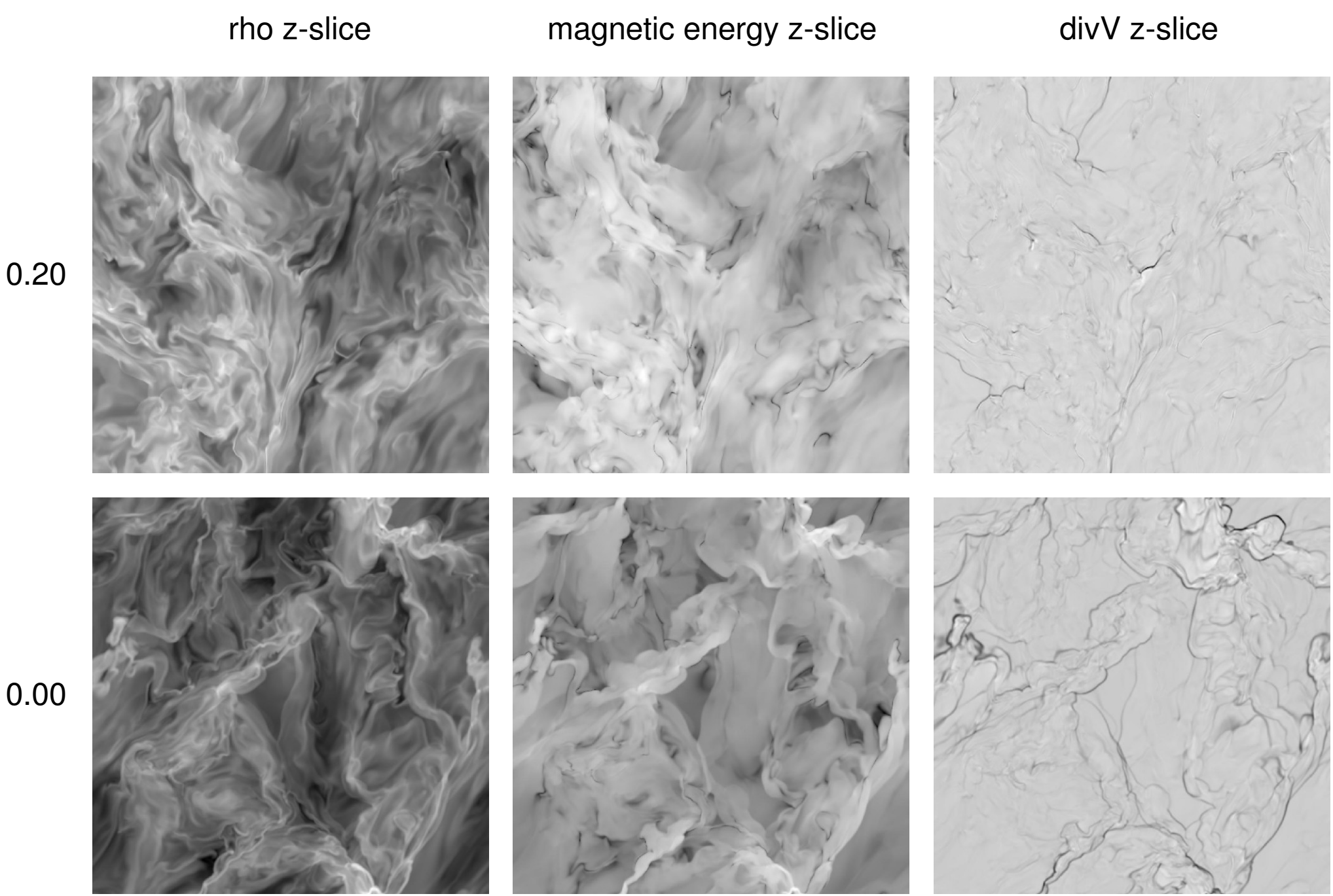
FLASH results – MHD 512^3 polytropic eos rho z-slice, Be-slice, divV z-slice



FLASH results – MHD 512^3 polytropic eos rho z-slice, Be-slice, divV z-slice

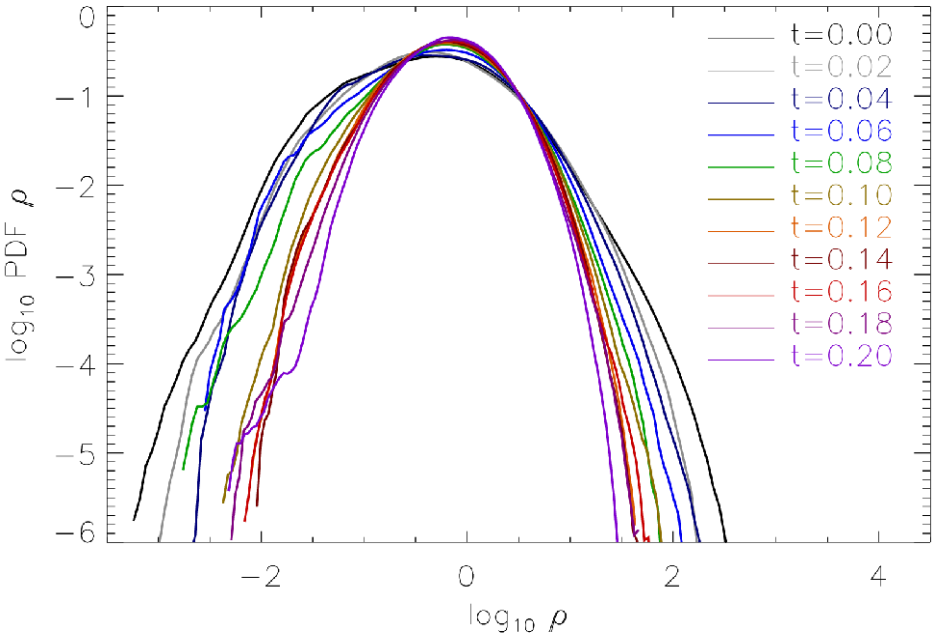


FLASH results – MHD 512^3 polytropic eos rho z-slice, Be-slice, divV z-slice

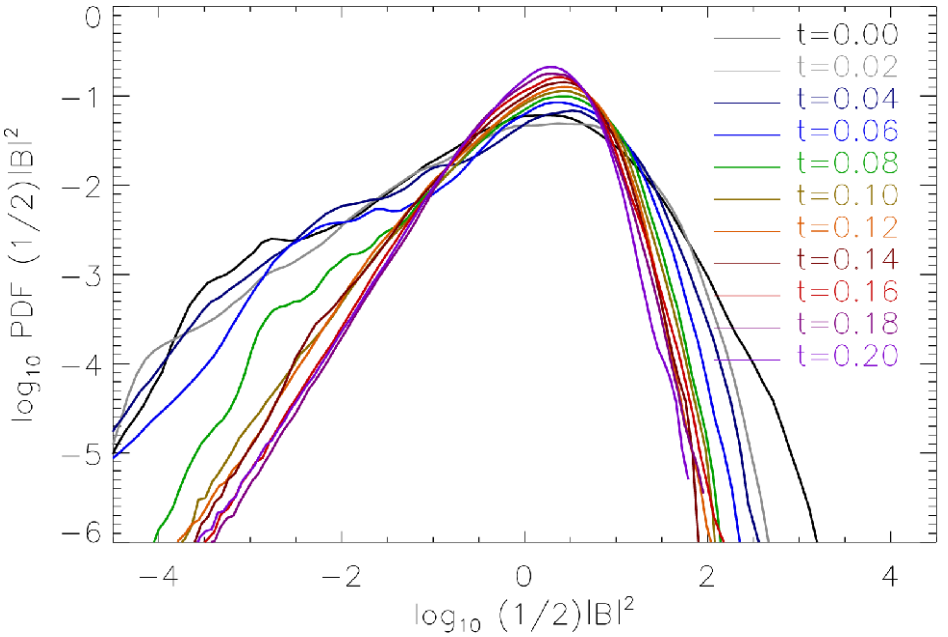


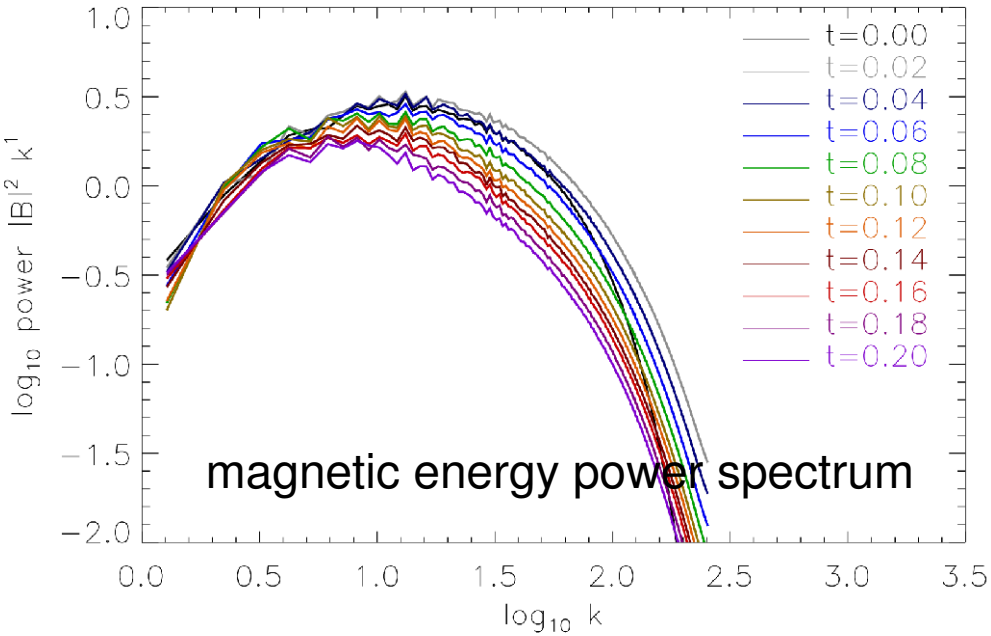
FLASH results – MHD 512^3 polytropic eos PDFs + magnetic spectrum

density PDF

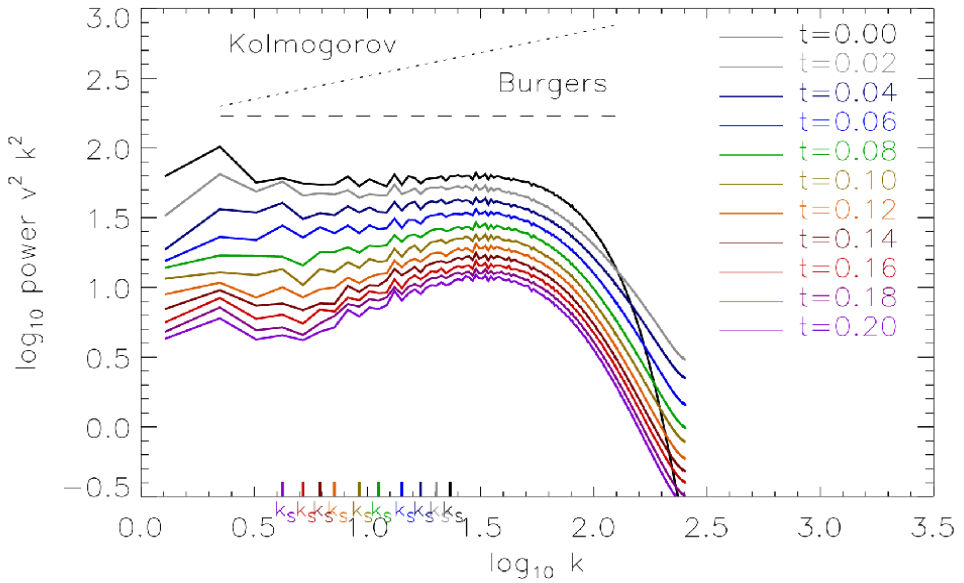


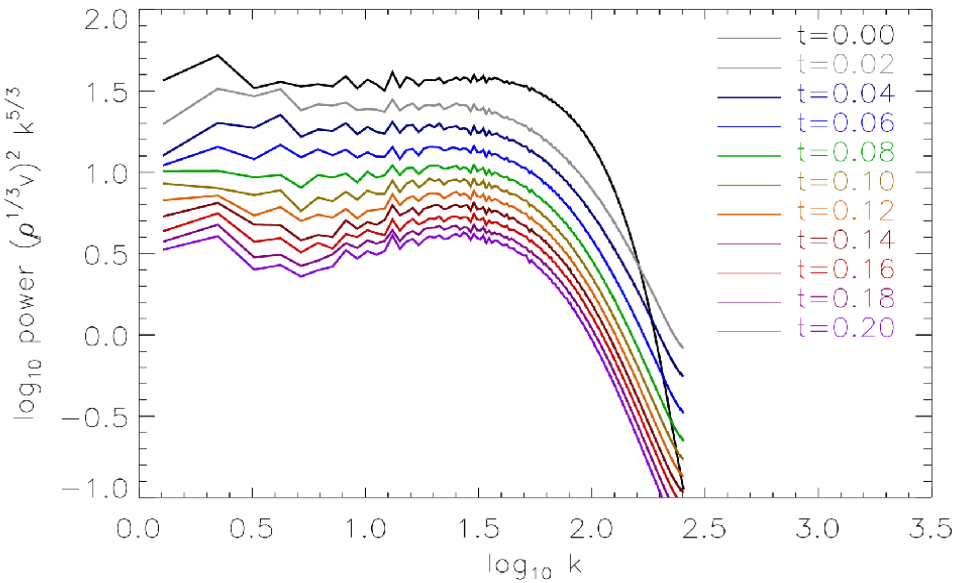
magnetic energy PDF

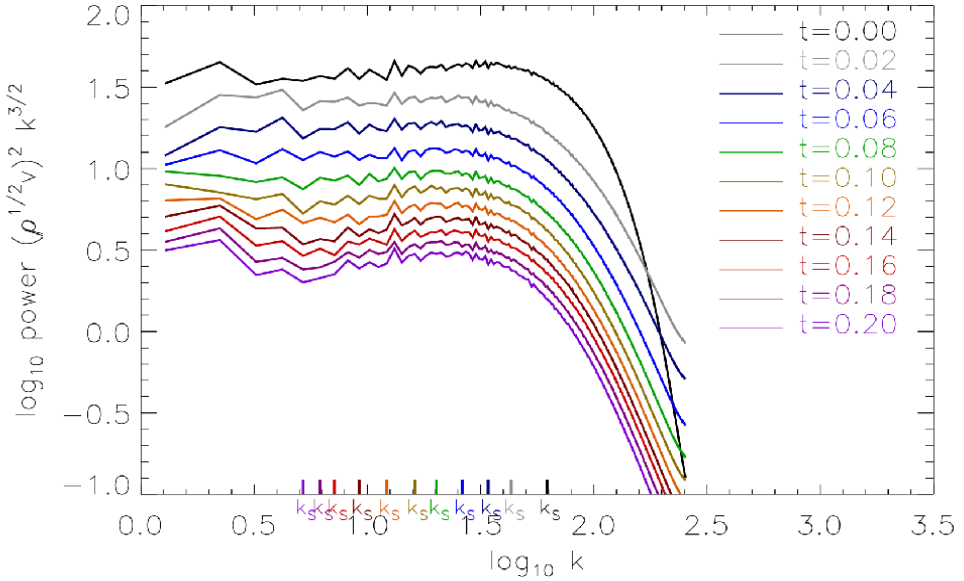


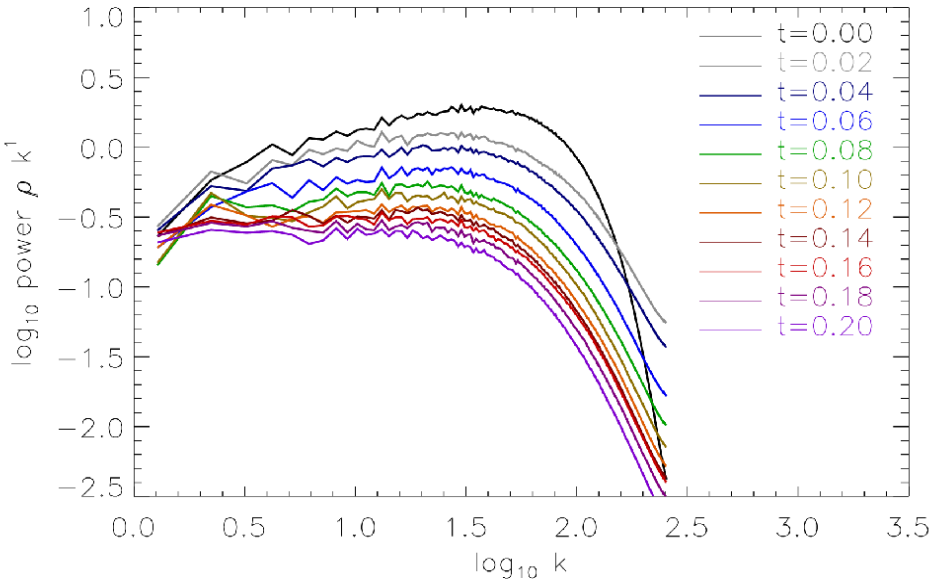


FLASH results – MHD 512^3 polytropic eos power spectra



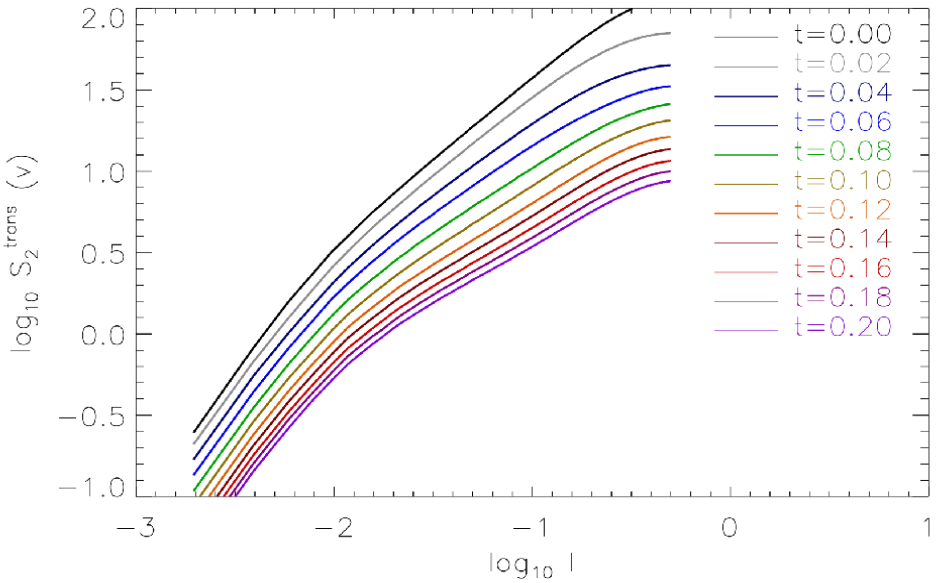




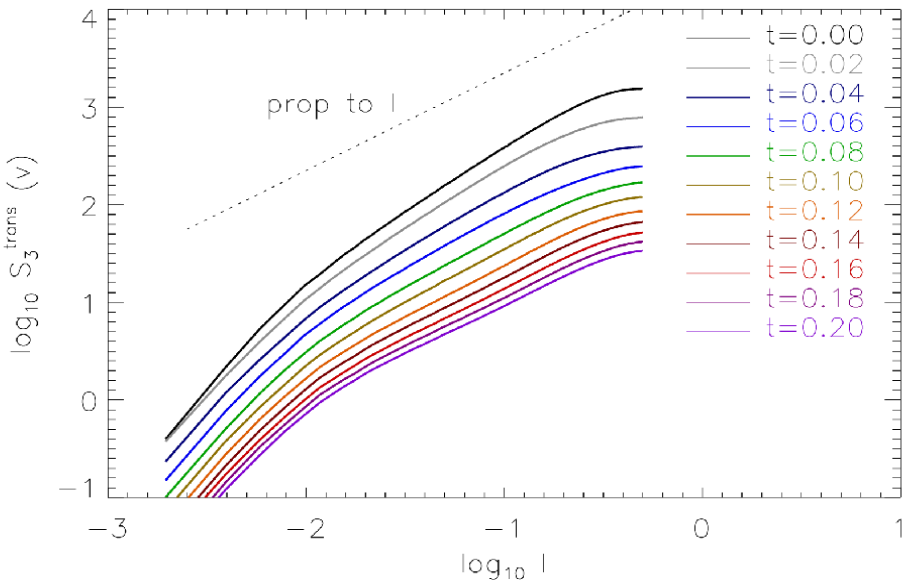


FLASH results – MHD 512^3 polytropic eos structure functions

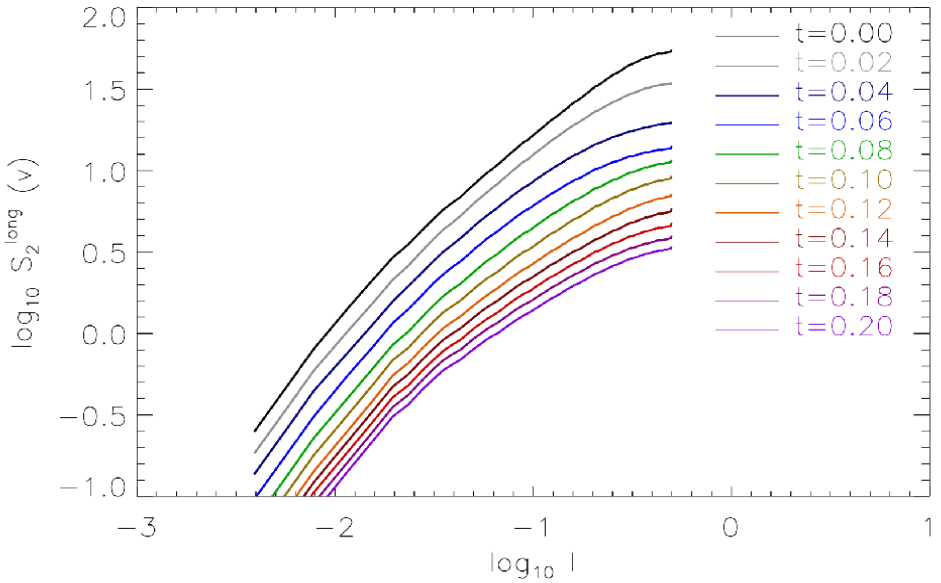
2^{nd} order transversal



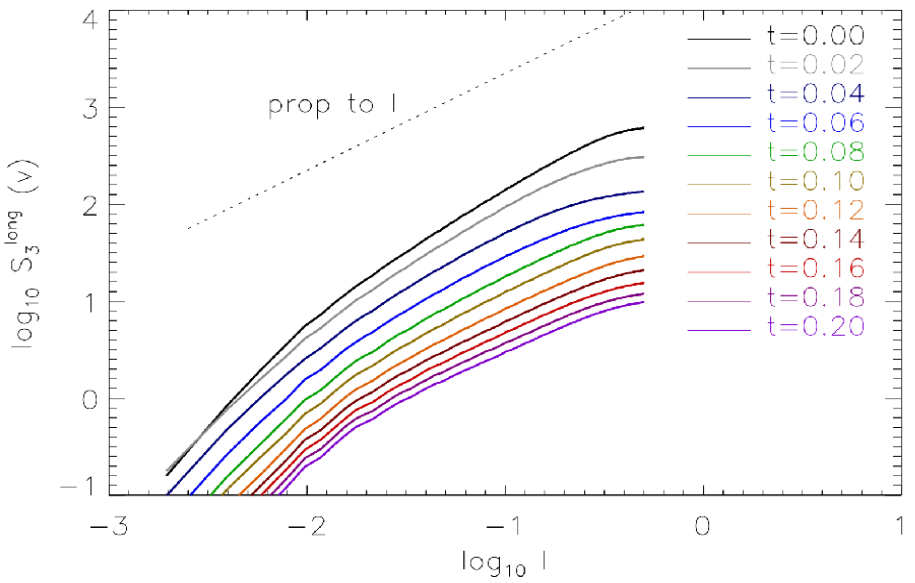
3^{rd} order transversal



2^{nd} order longitudinal



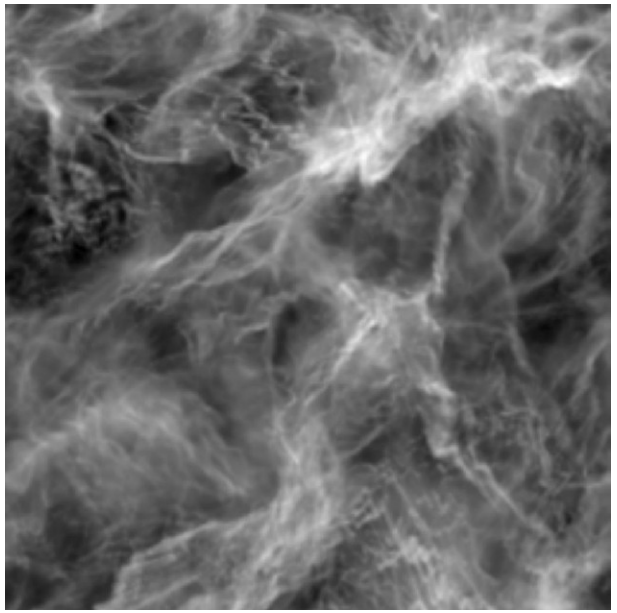
3^{rd} order longitudinal

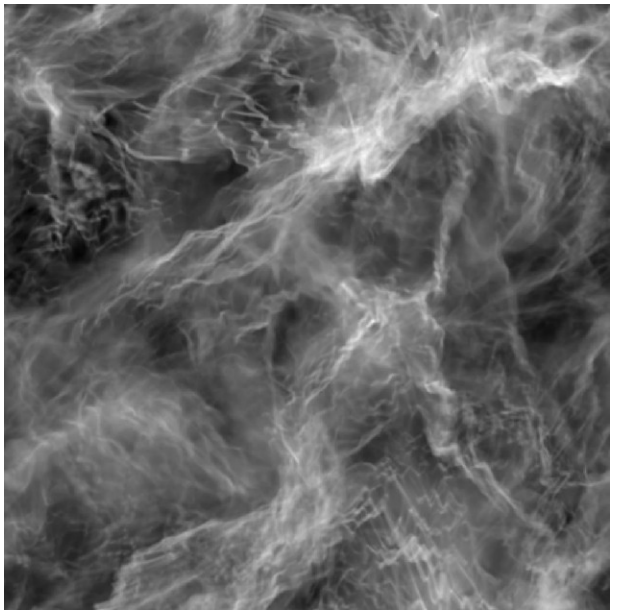


FLASH results – resolution study + HD vs MHD column density z

t = 0.00

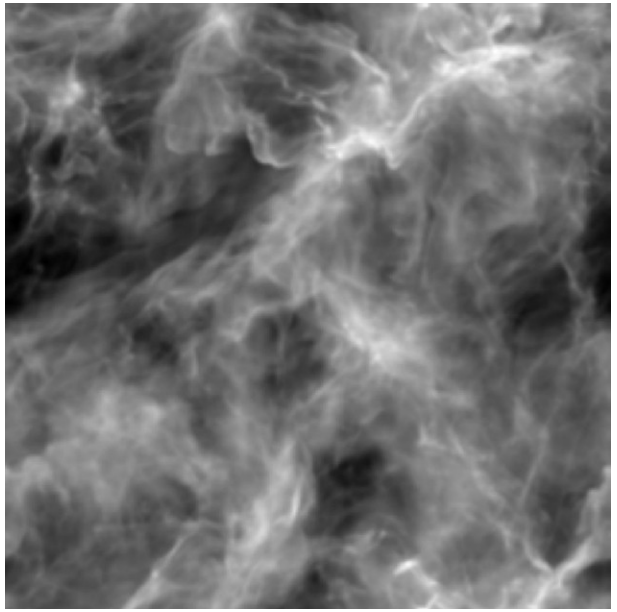
HD 256^3

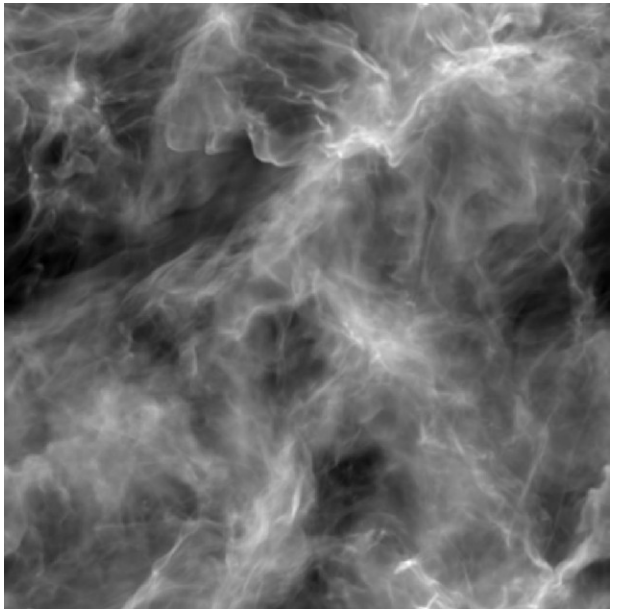




HD 512^3

MHD 256^3



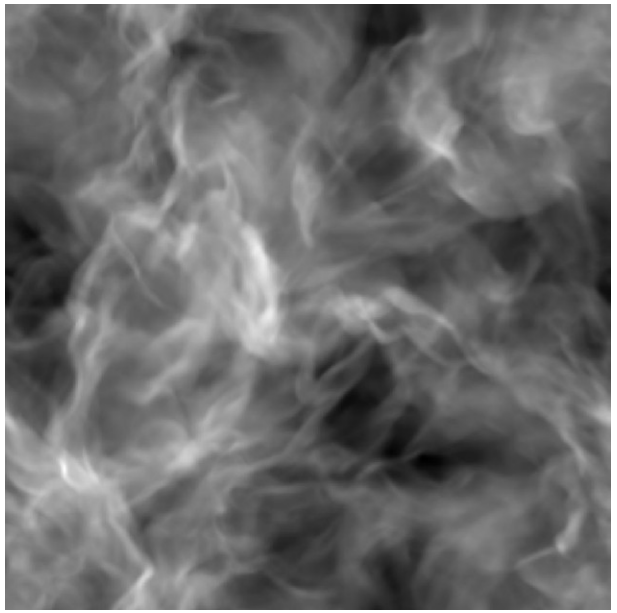


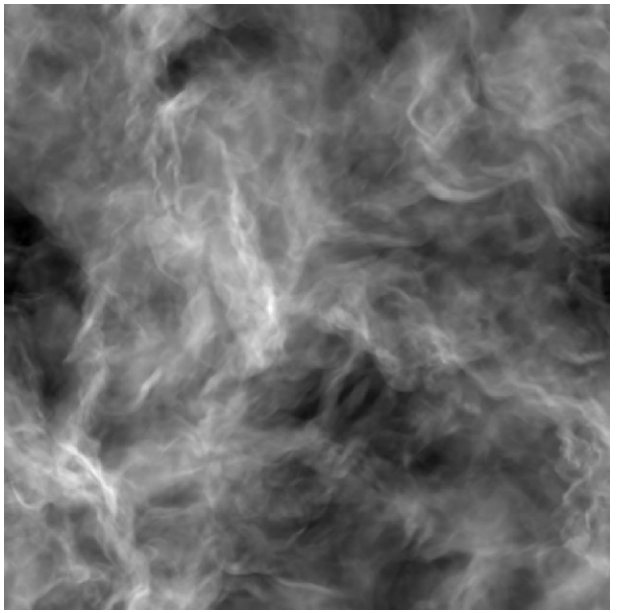
MHD 512^3

FLASH results – resolution study + HD vs MHD column density z

t = 0.10

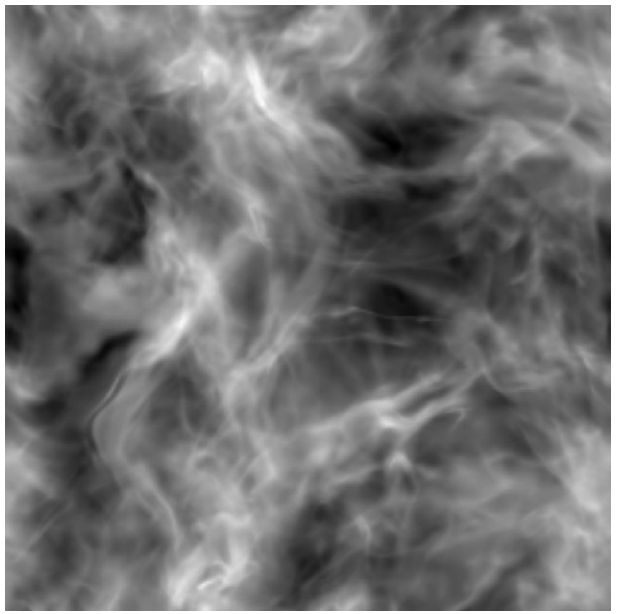
HD 256^3

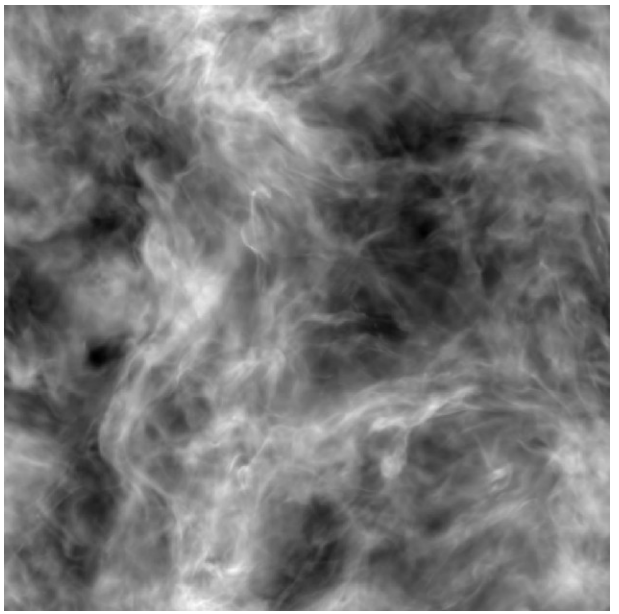




HD 512^3

MHD 256^3



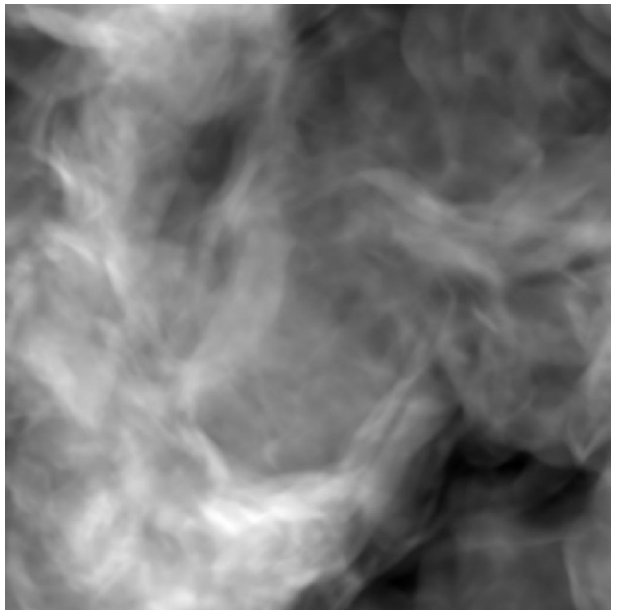


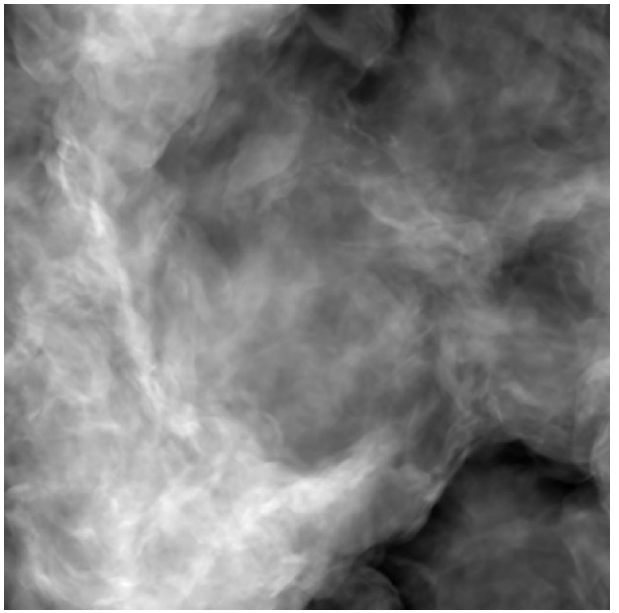
MHD 512^3

FLASH results – resolution study + HD vs MHD column density z

t = 0.20

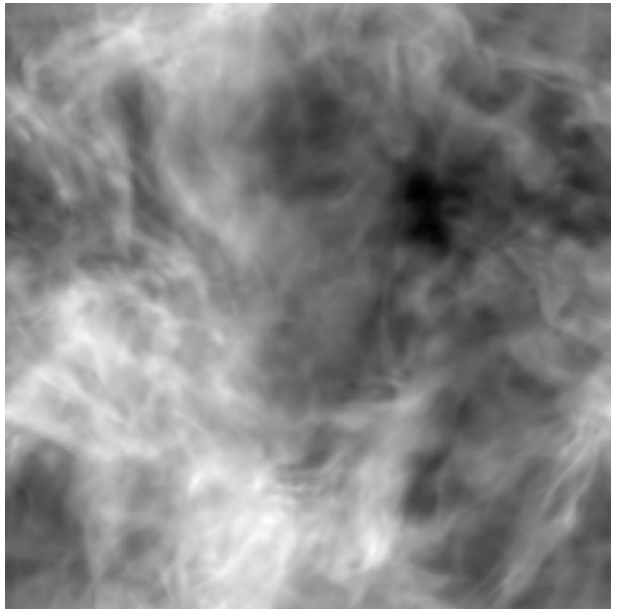
HD 256^3

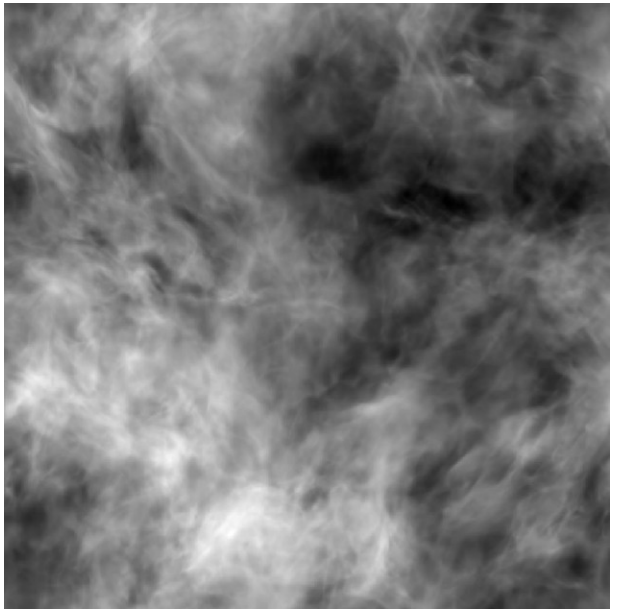




HD 512^3

MHD 256^3



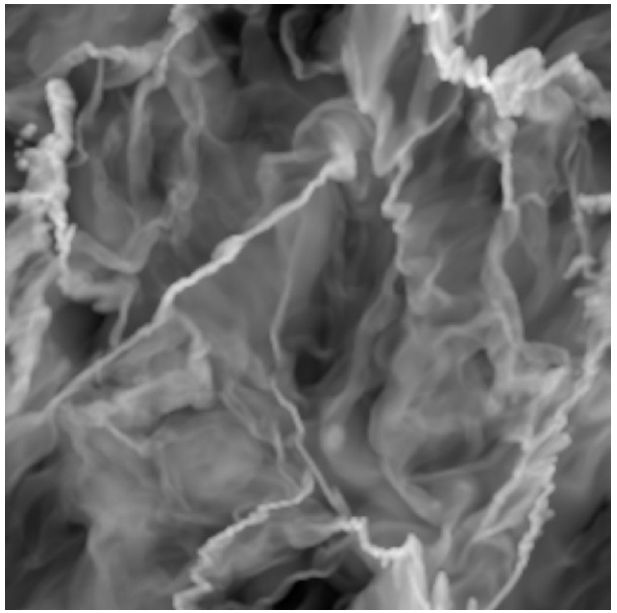


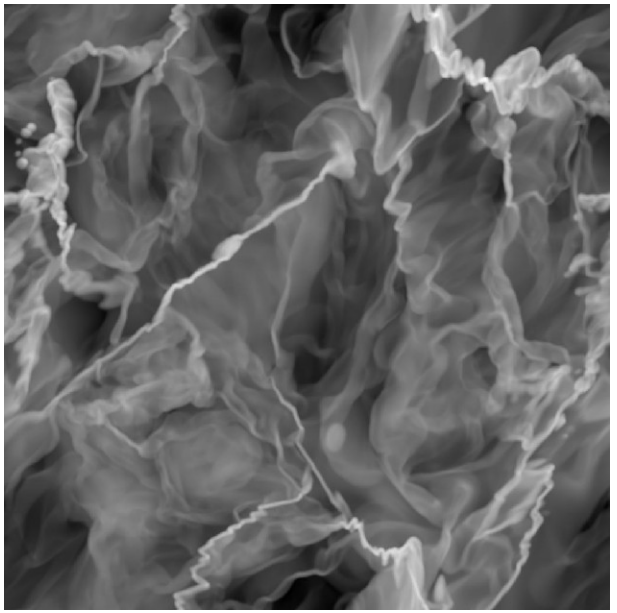
MHD 512^3

FLASH results – resolution study + HD vs MHD rho z-slice

t = 0.00

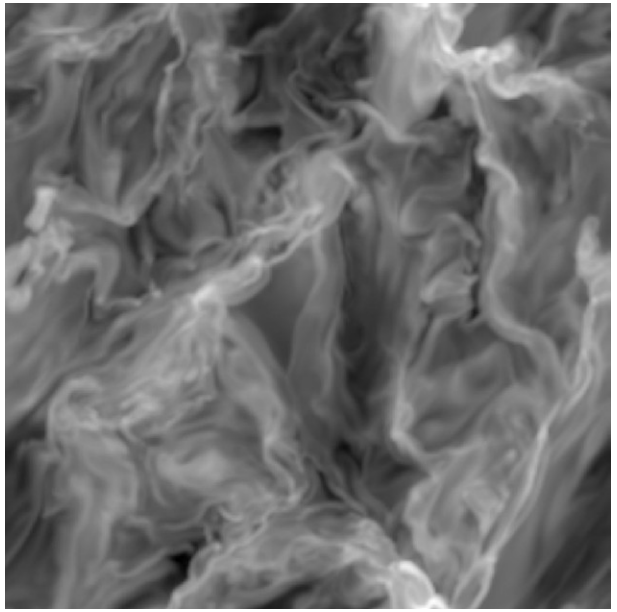
HD 256^3

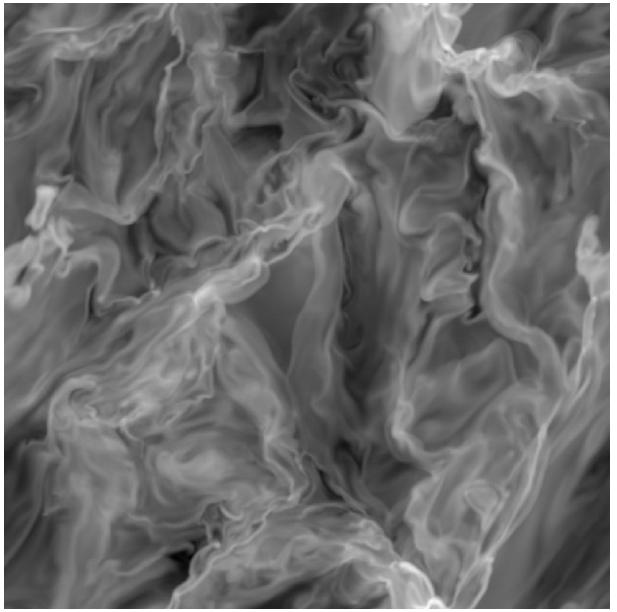




HD 512^3

MHD 256^3



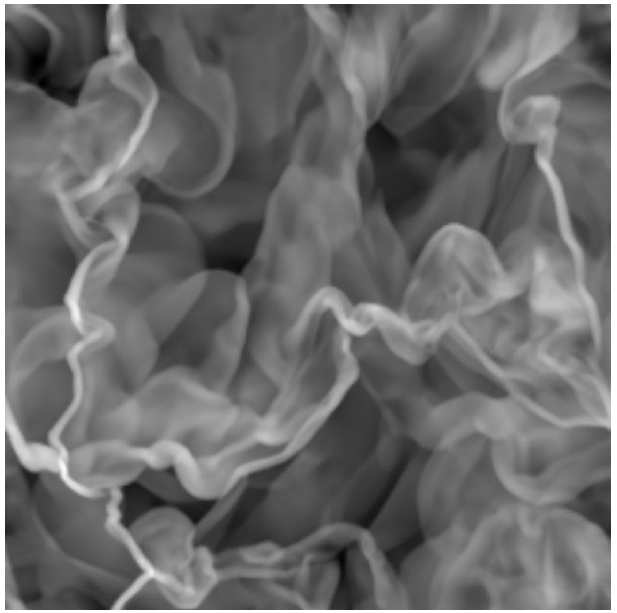


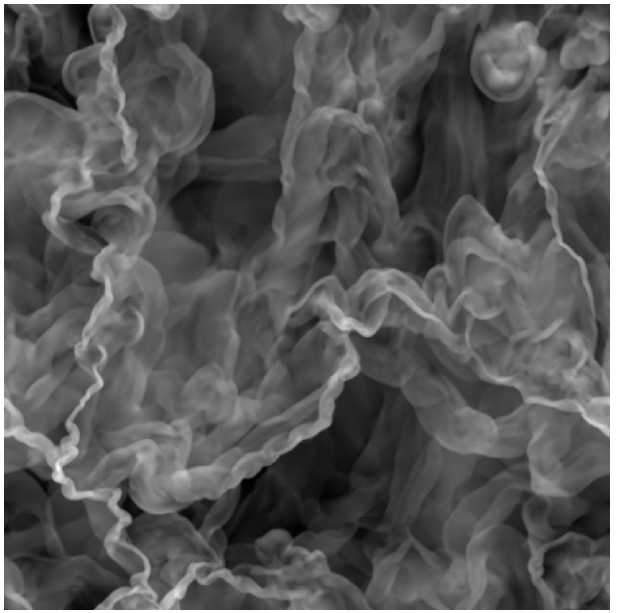
MHD 512^3

FLASH results – resolution study + HD vs MHD rho z-slice

t = 0.10

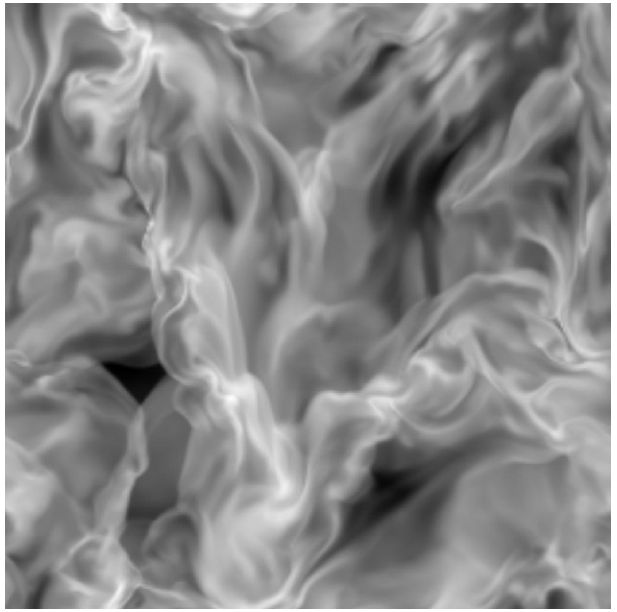
HD 256^3

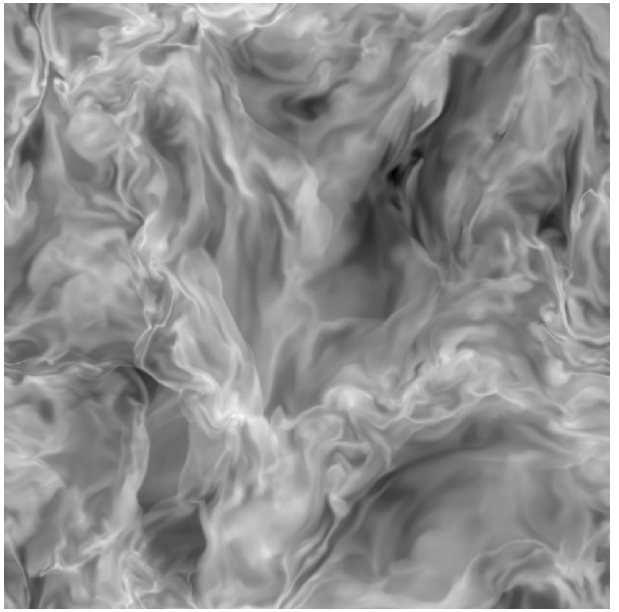




HD 512^3

MHD 256^3



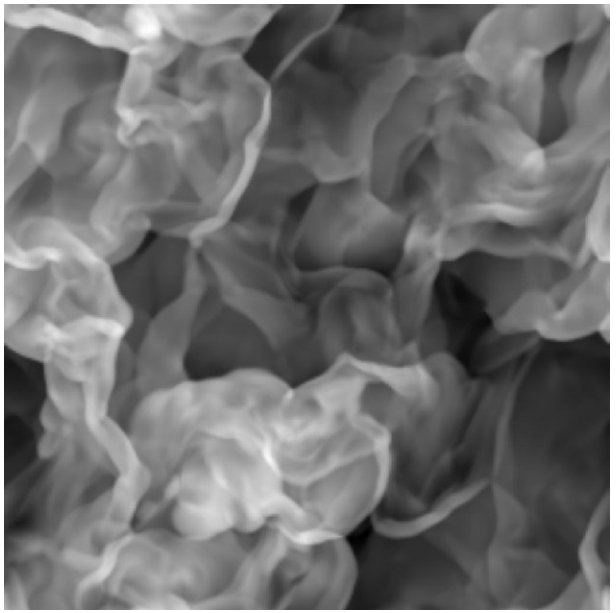


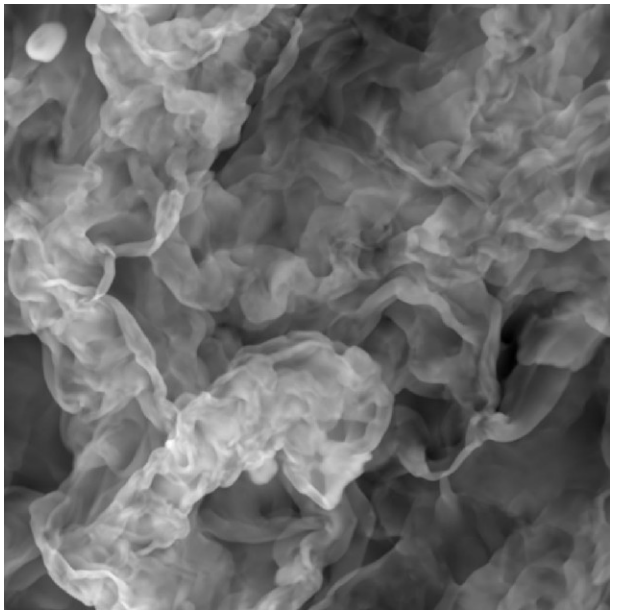
MHD 512^3

FLASH results – resolution study + HD vs MHD rho z-slice

t = 0.20

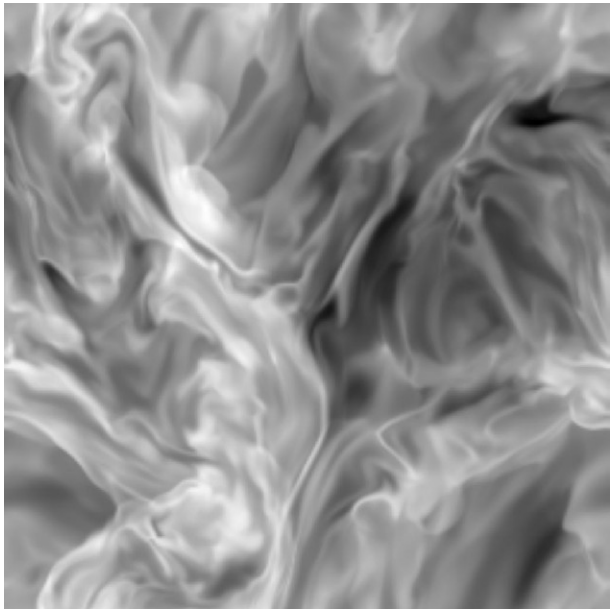
HD 256^3

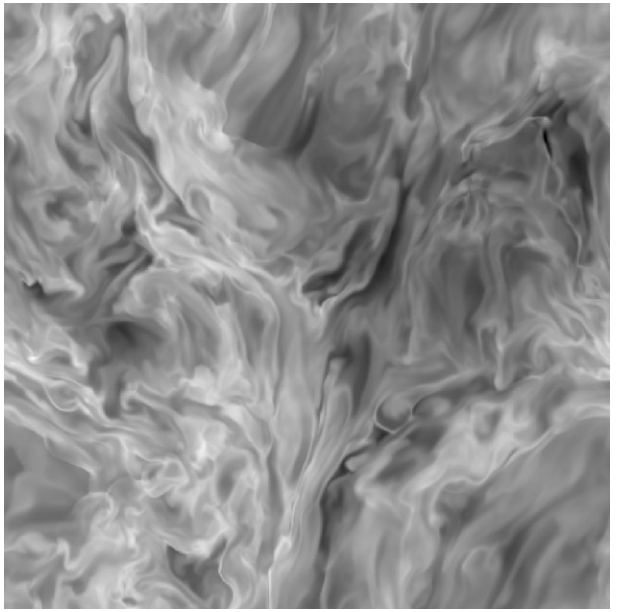




HD 512^3

MHD 256^3



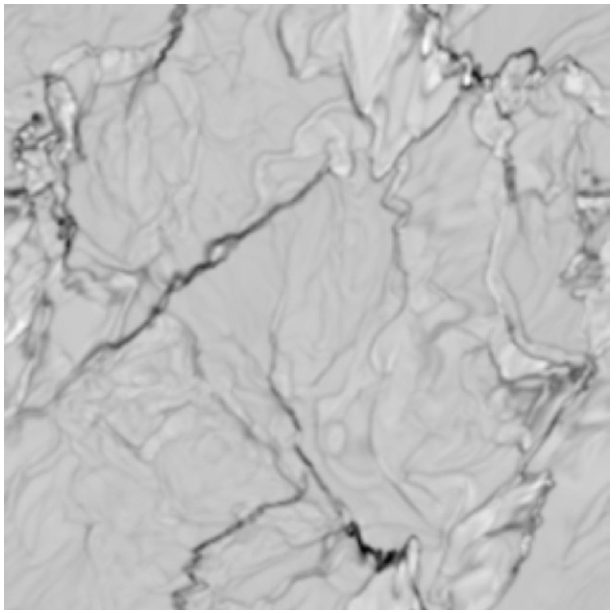


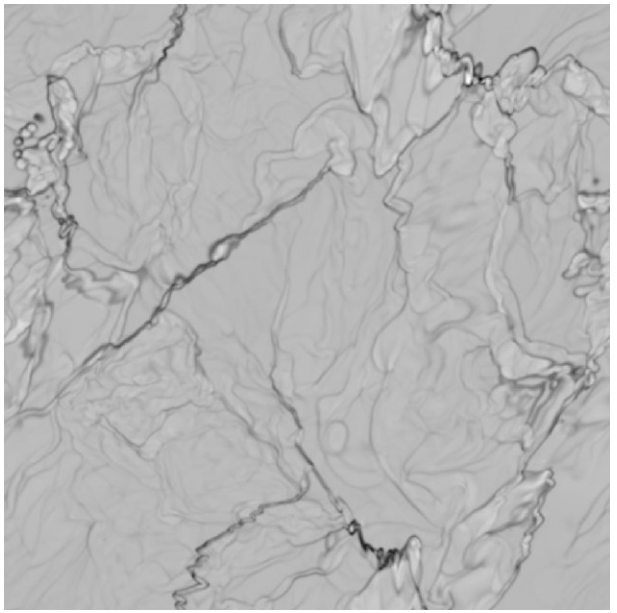
MHD 512^3

FLASH results – resolution study + HD vs MHD divV z-slice

t = 0.00

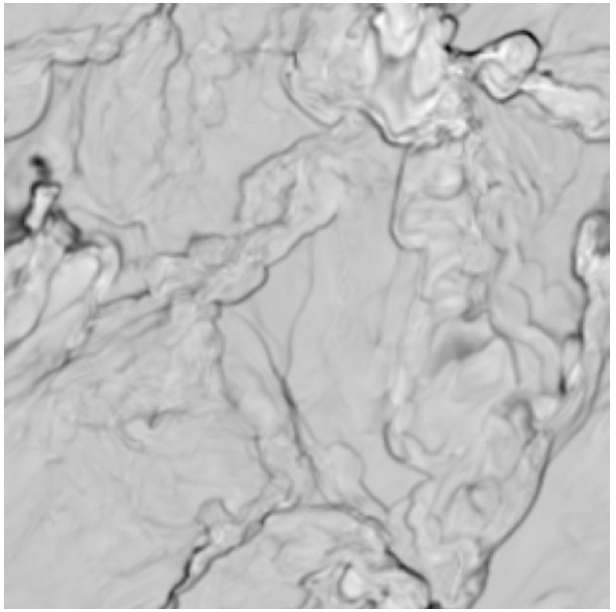
HD 256^3

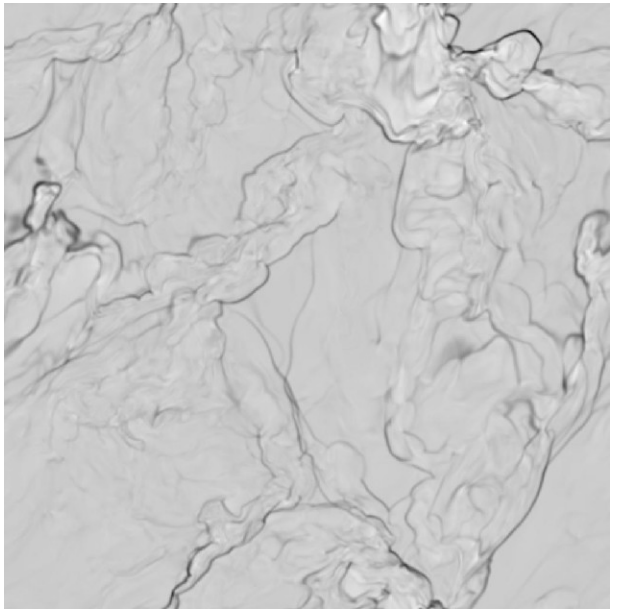




HD 512^3

MHD 256^3



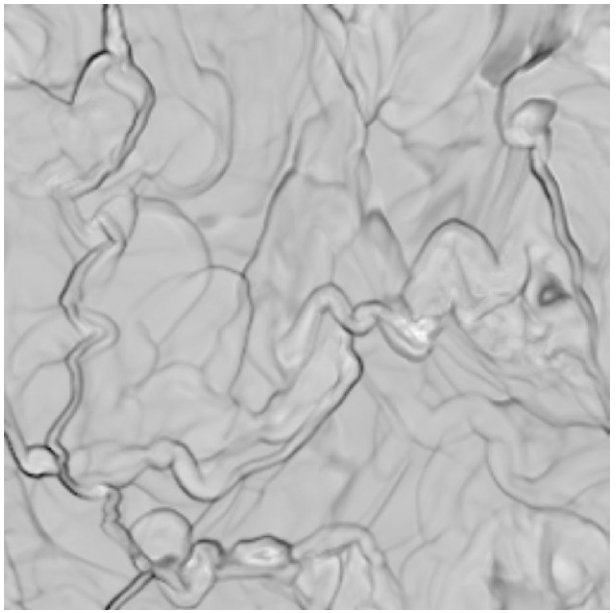


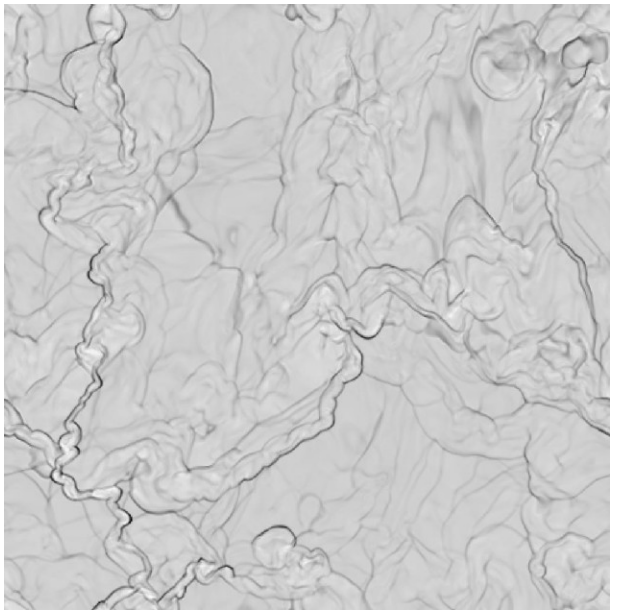
MHD 512^3

FLASH results – resolution study + HD vs MHD divV z-slice

t = 0.10

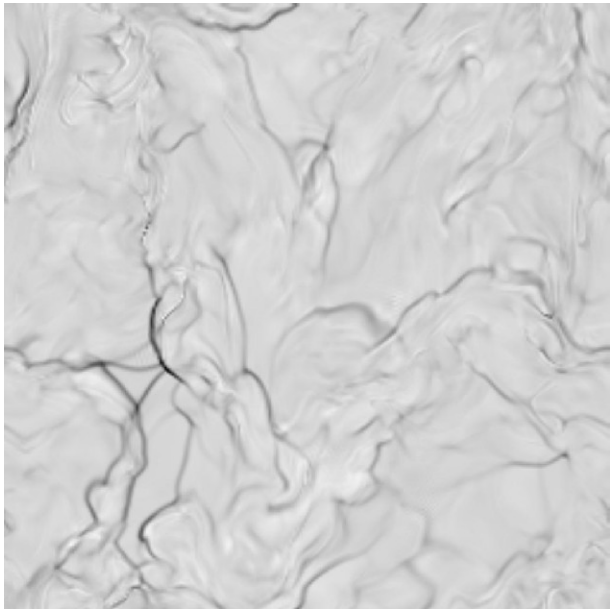
HD 256^3

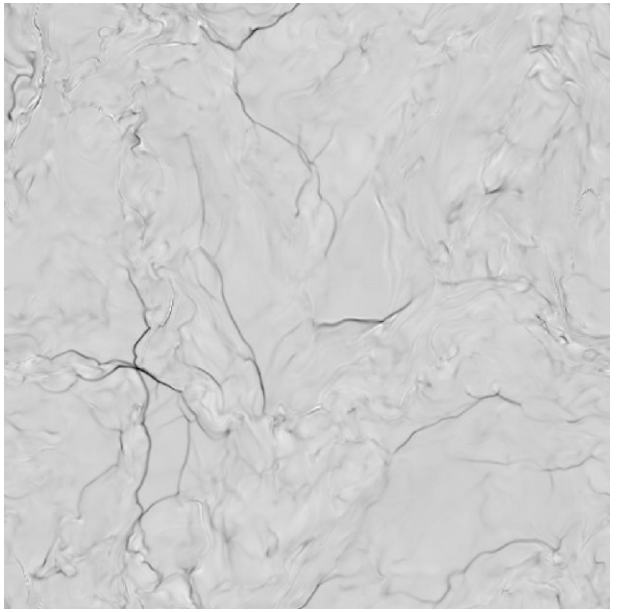




HD 512^3

MHD 256^3



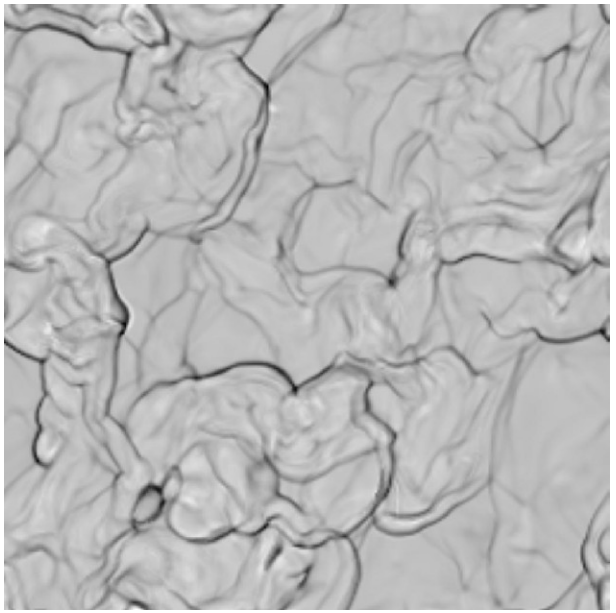


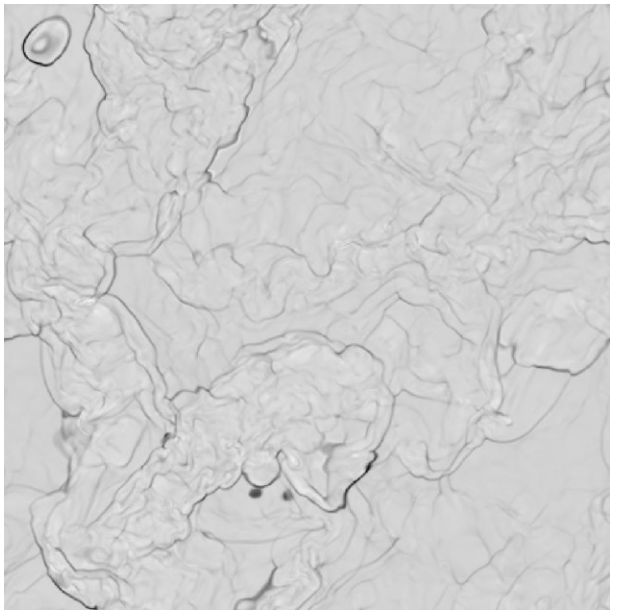
MHD 512^3

FLASH results – resolution study + HD vs MHD divV z-slice

t = 0.20

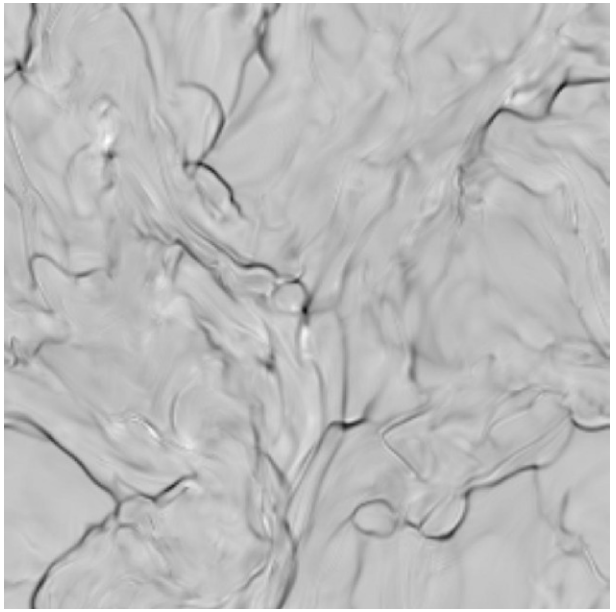
HD 256^3

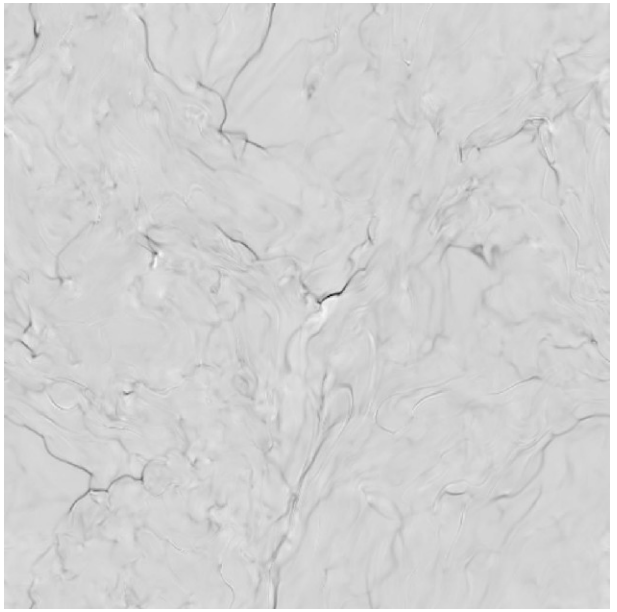




HD 512^3

MHD 256^3

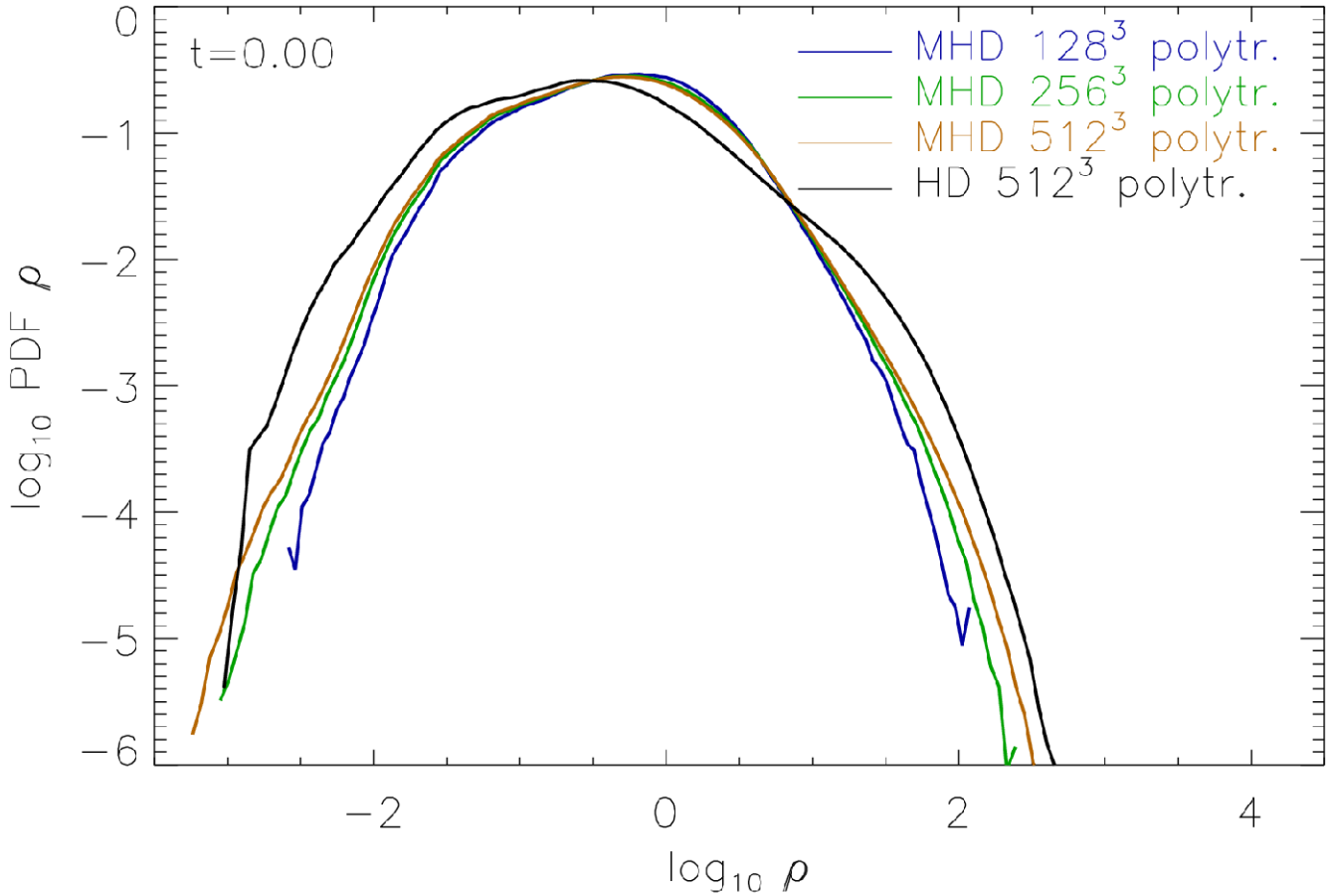




MHD 512^3

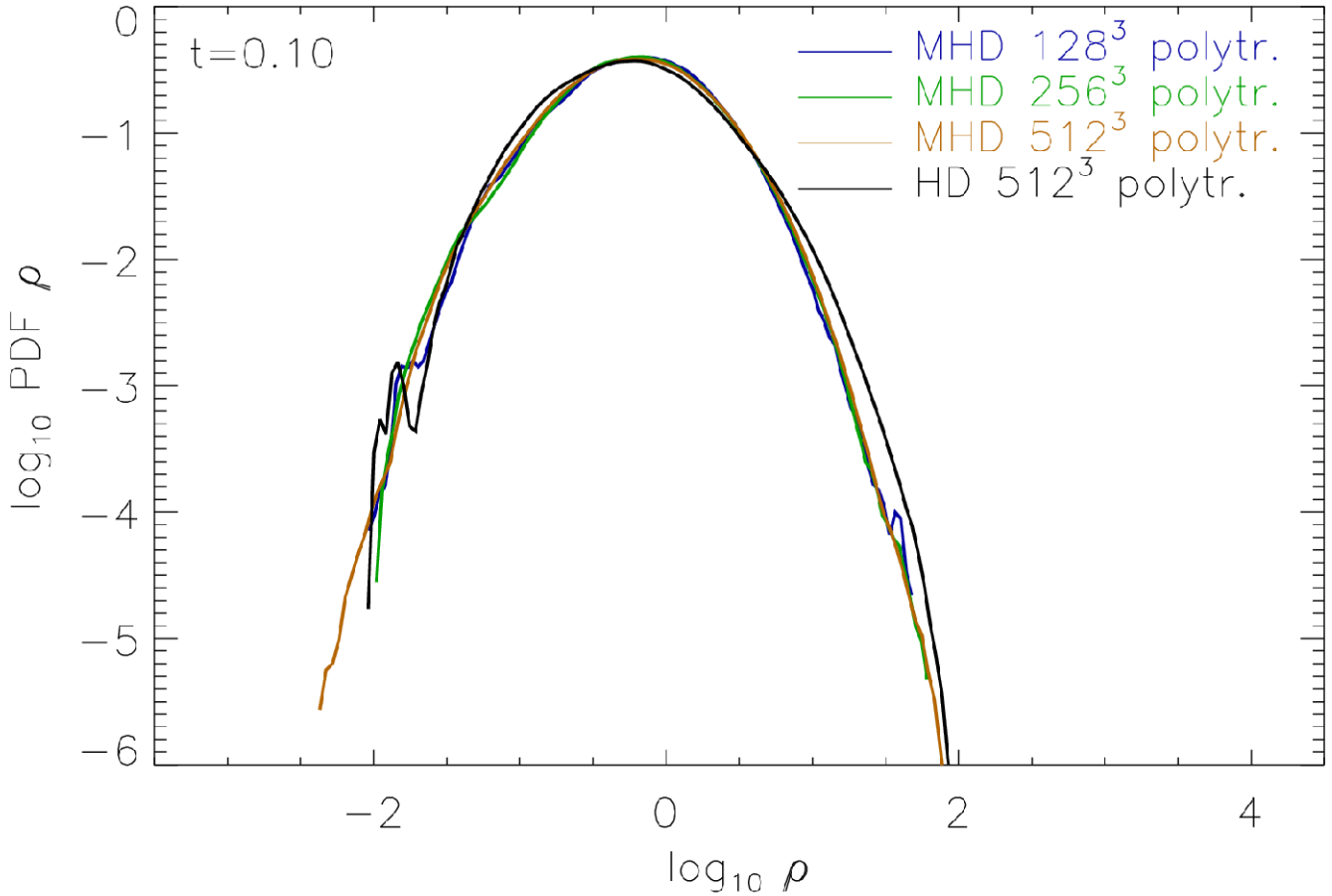
FLASH results – resolution study density PDF

t = 0.00



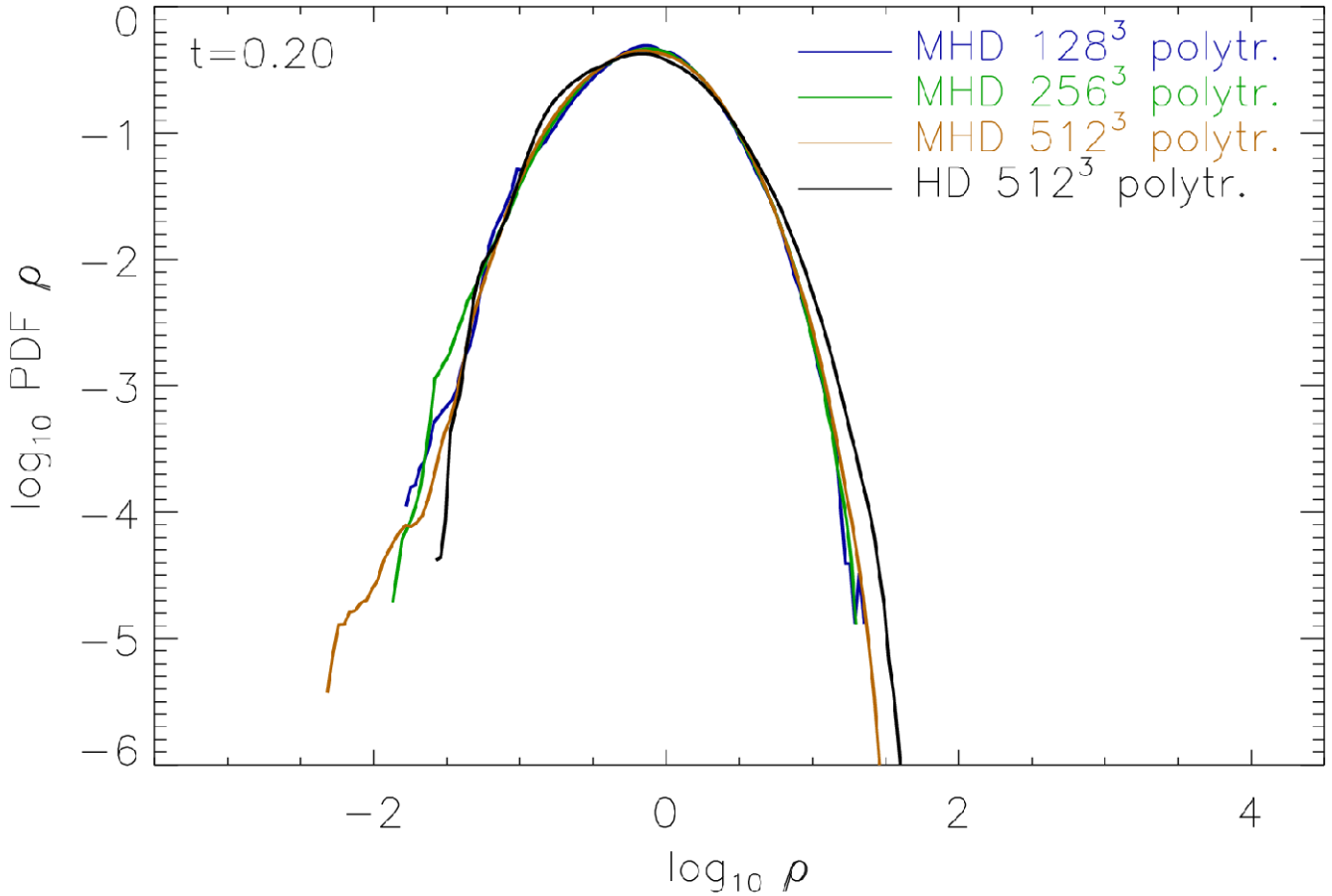
FLASH results – resolution study density PDF

t = 0.10



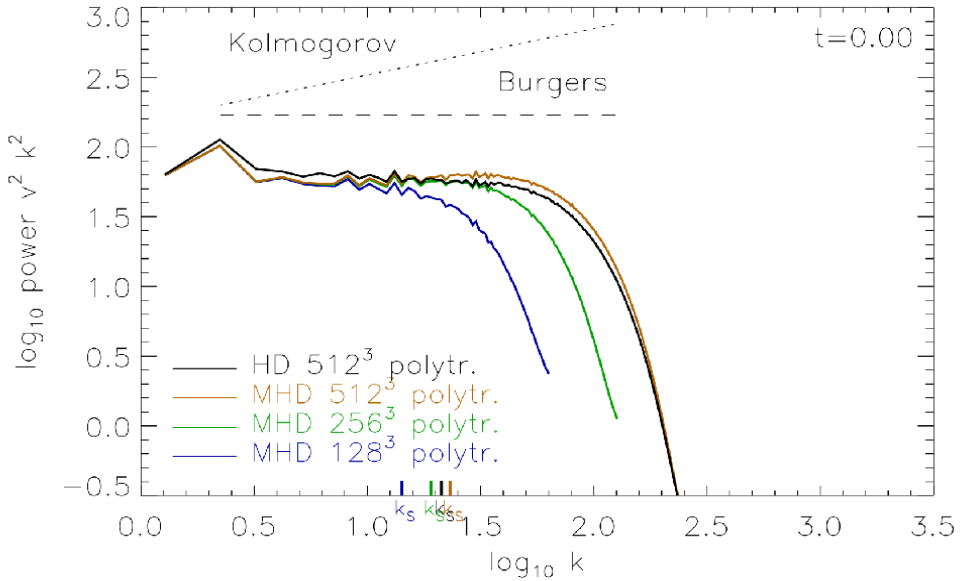
FLASH results – resolution study density PDF

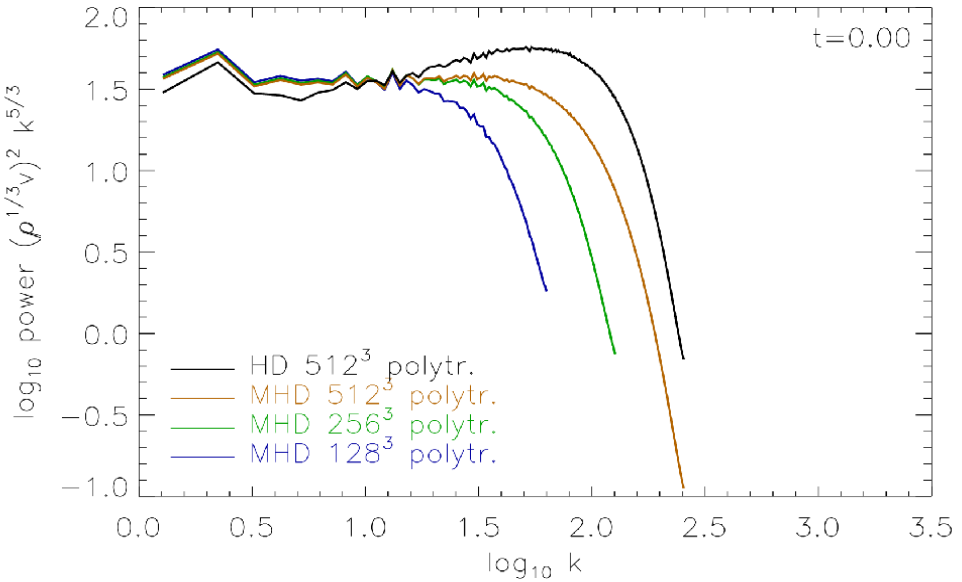
t = 0.20

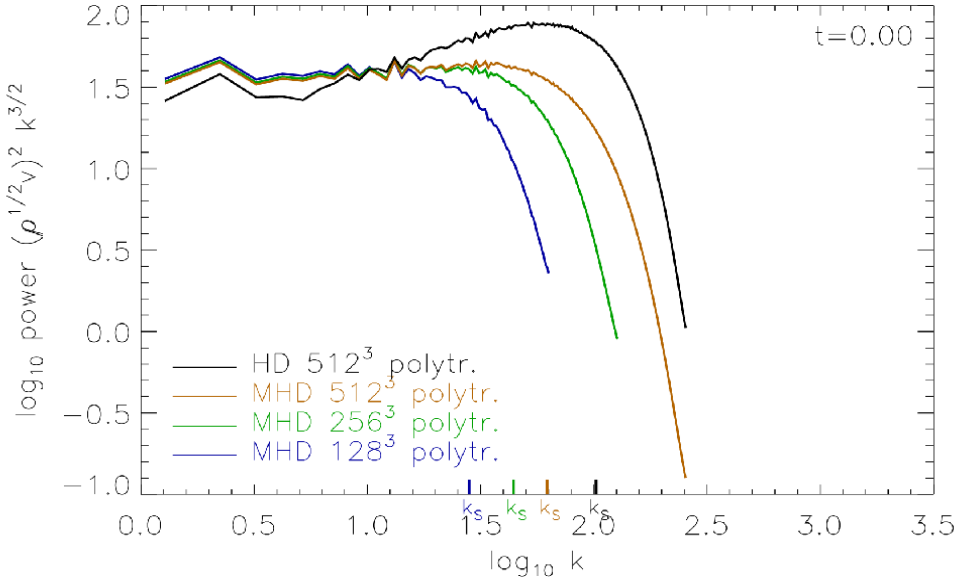


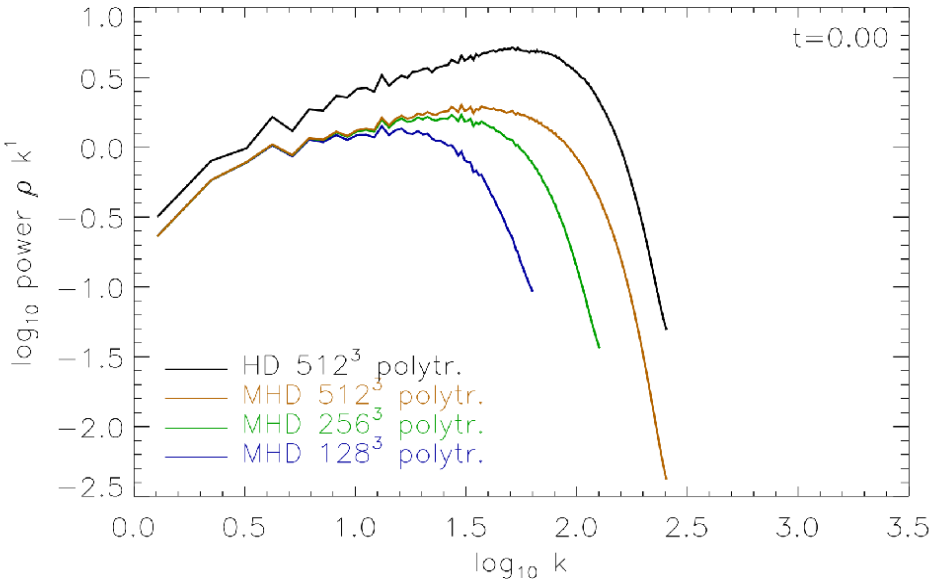
FLASH results – resolution study power spectra

t = 0.00



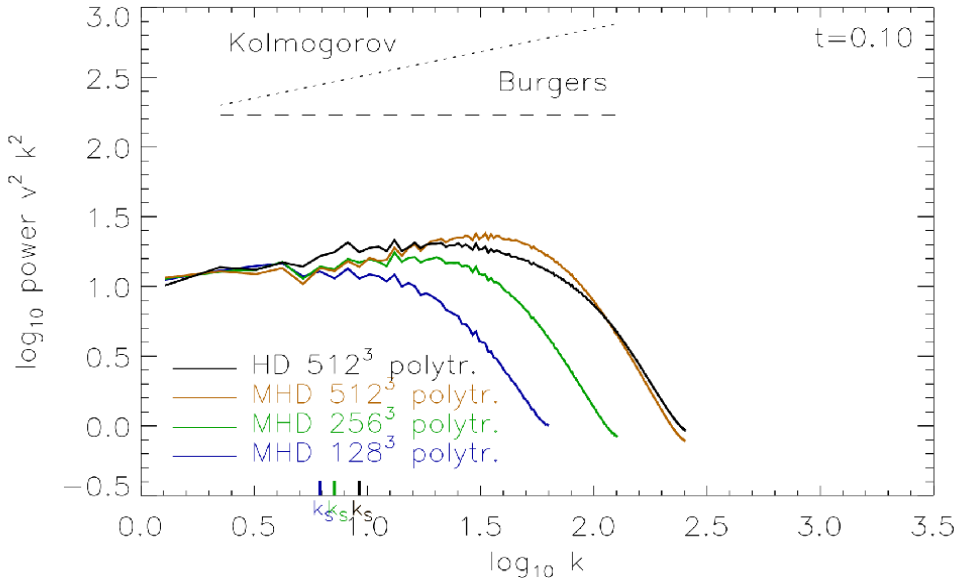


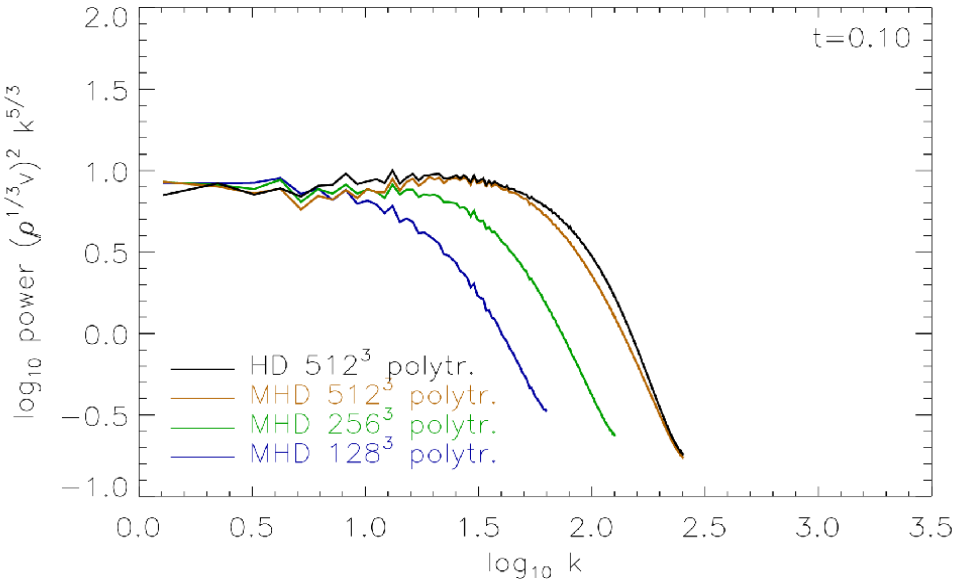


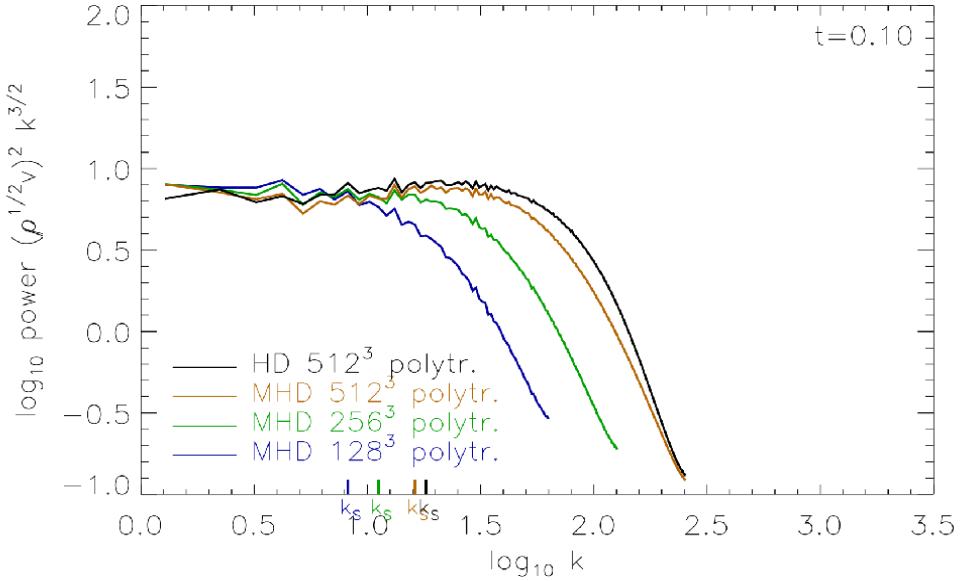


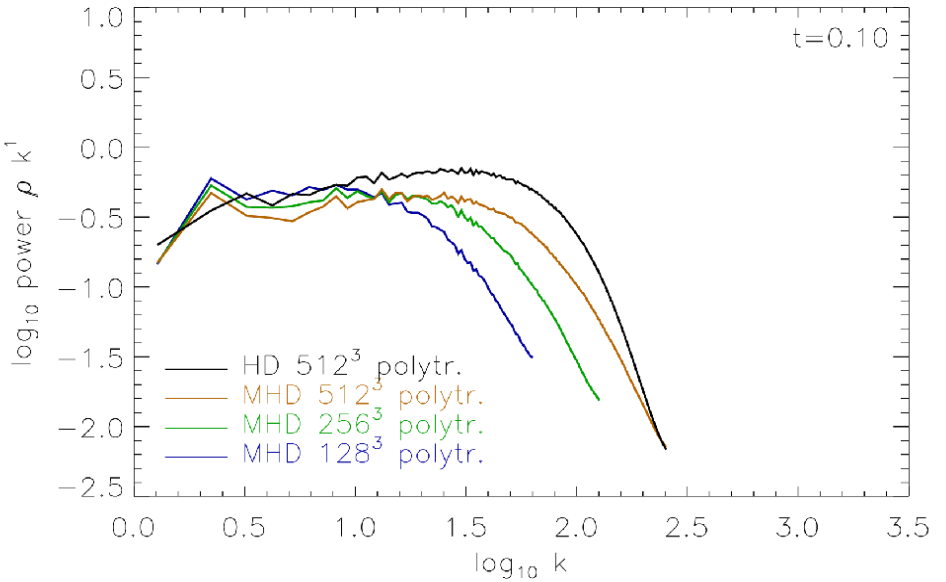
FLASH results – resolution study power spectra

t = 0.10



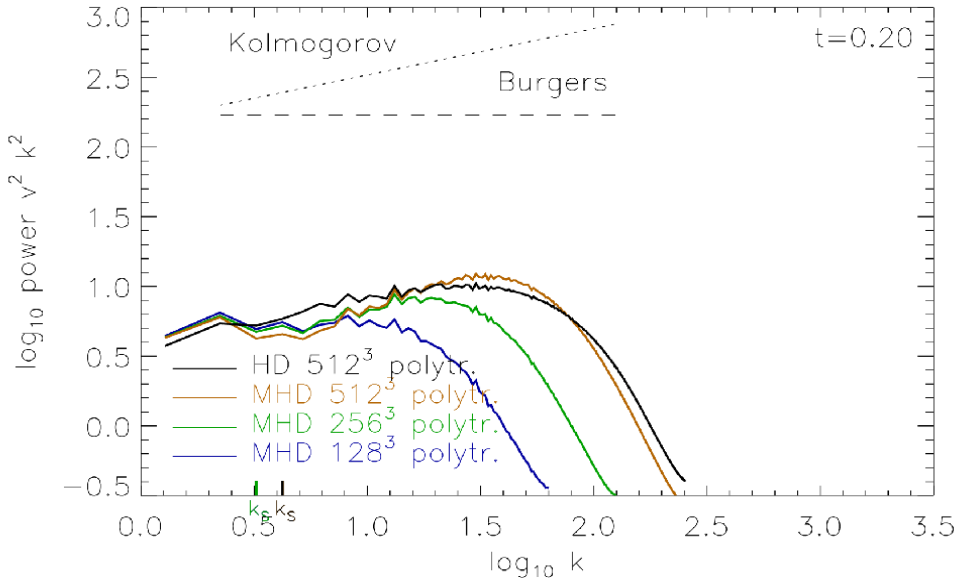


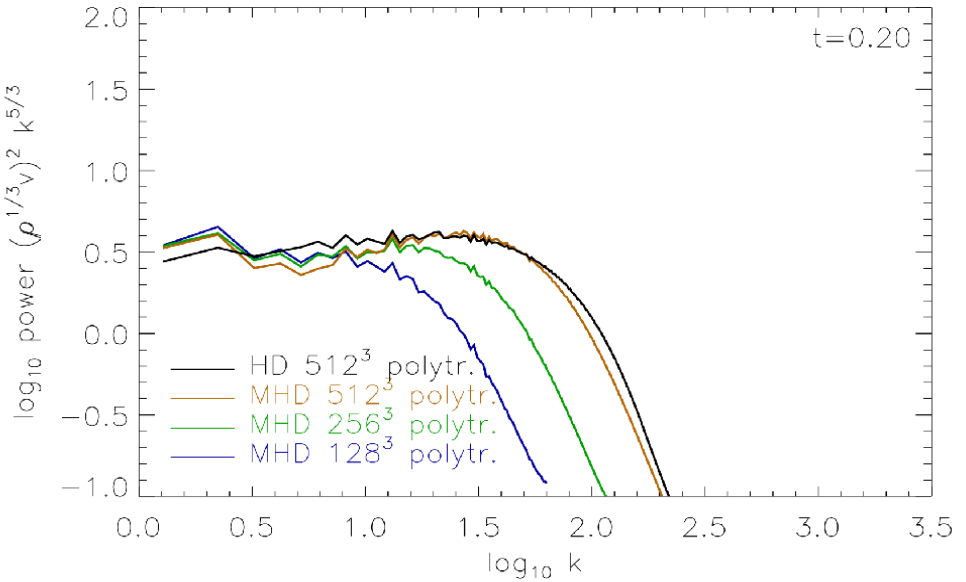


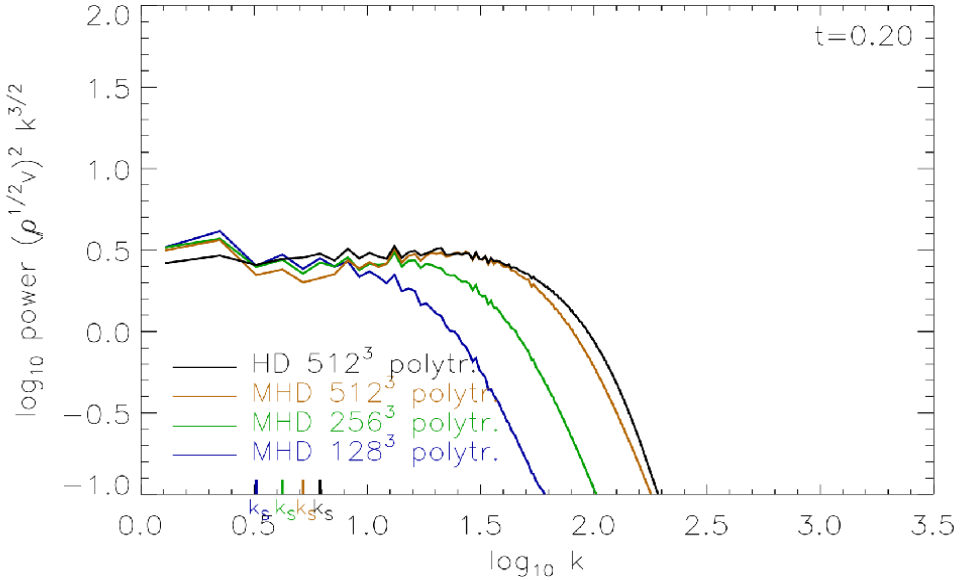


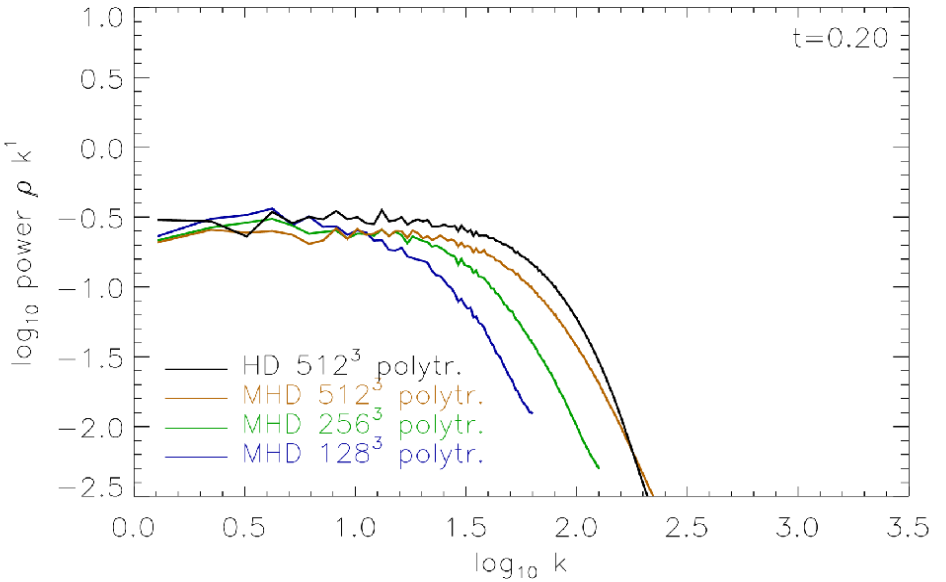
FLASH results – resolution study power spectra

t = 0.20





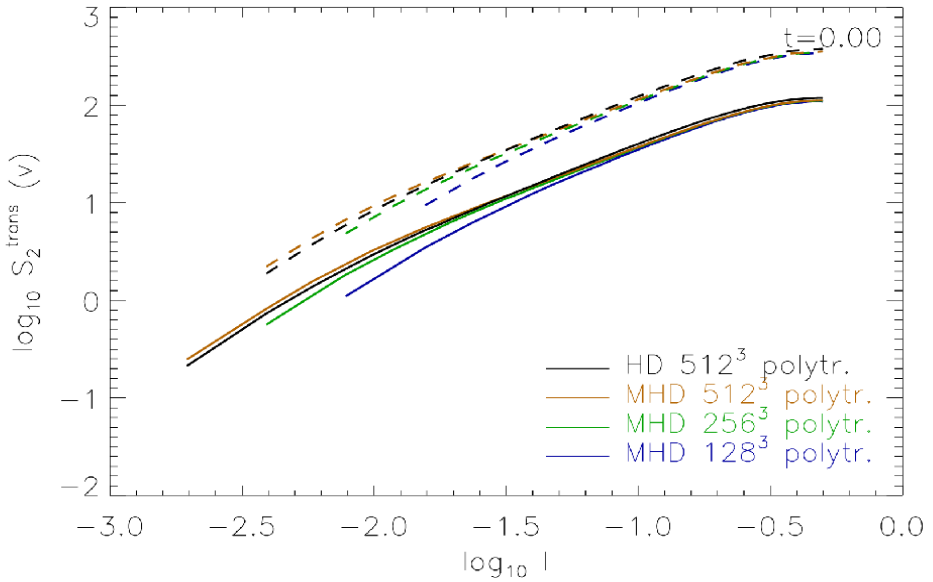




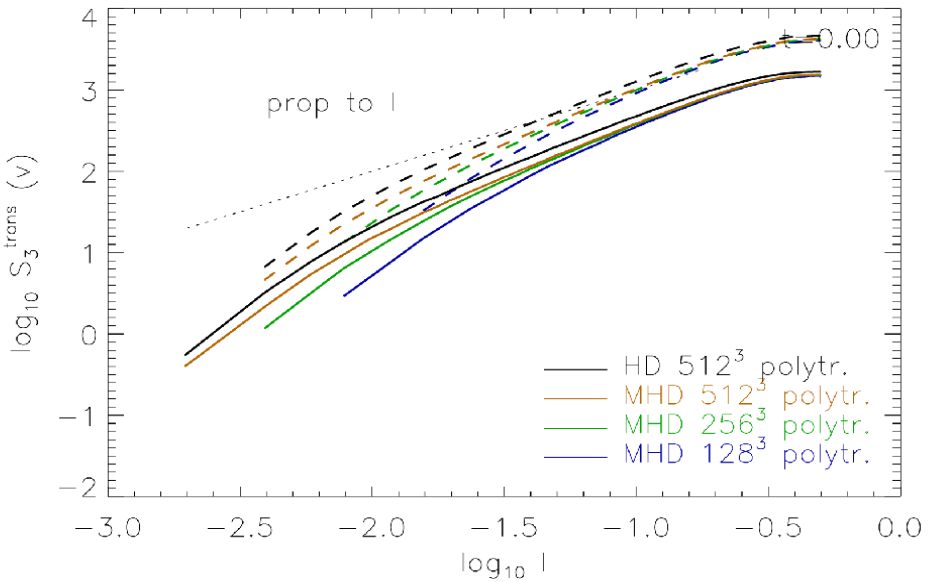
FLASH results – resolution study structure functions

t = 0.00

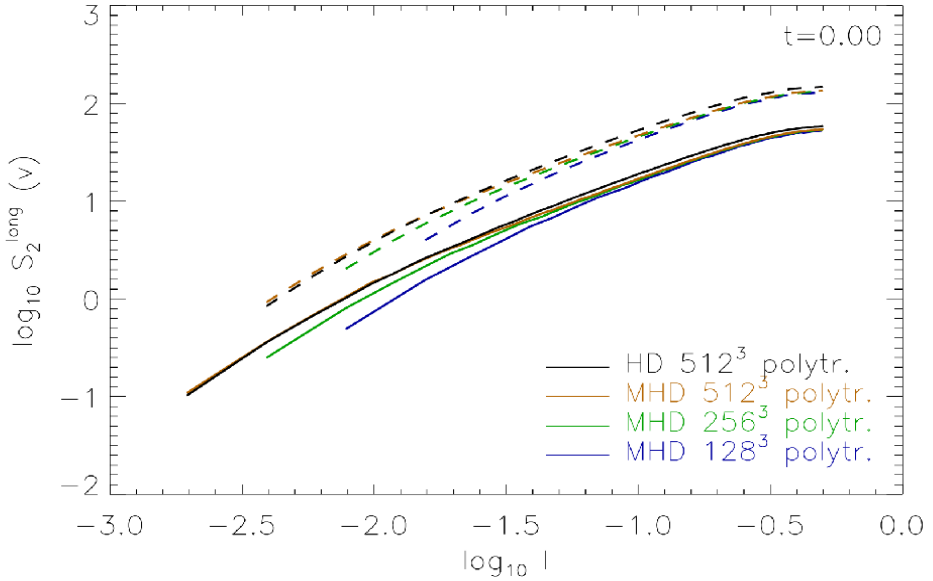
2nd order transversal



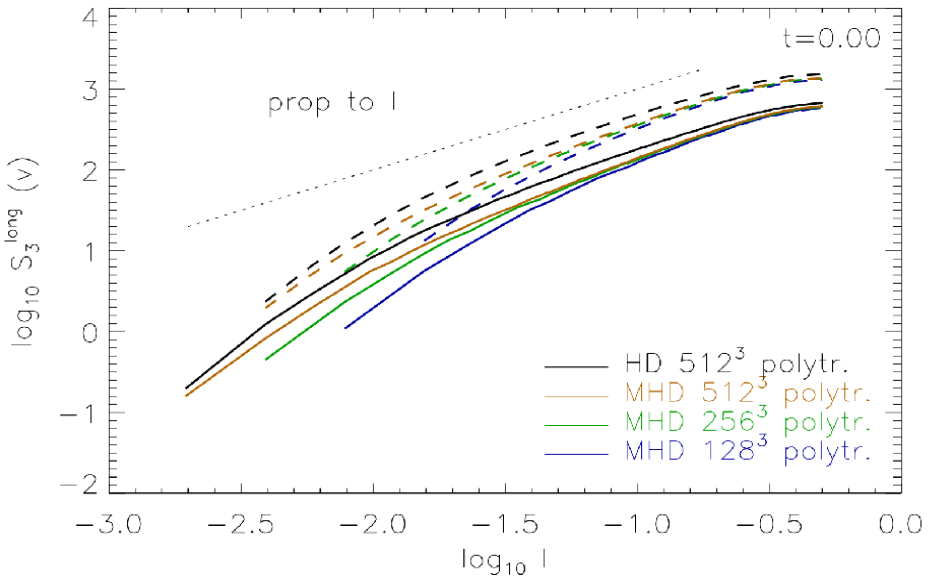
3rd order transversal



2nd order longitudinal



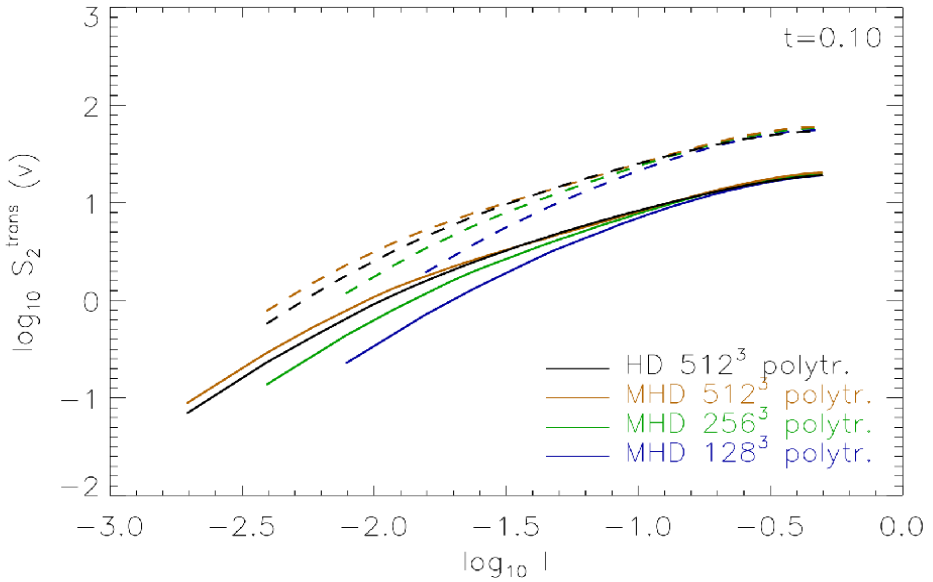
3rd order longitudinal



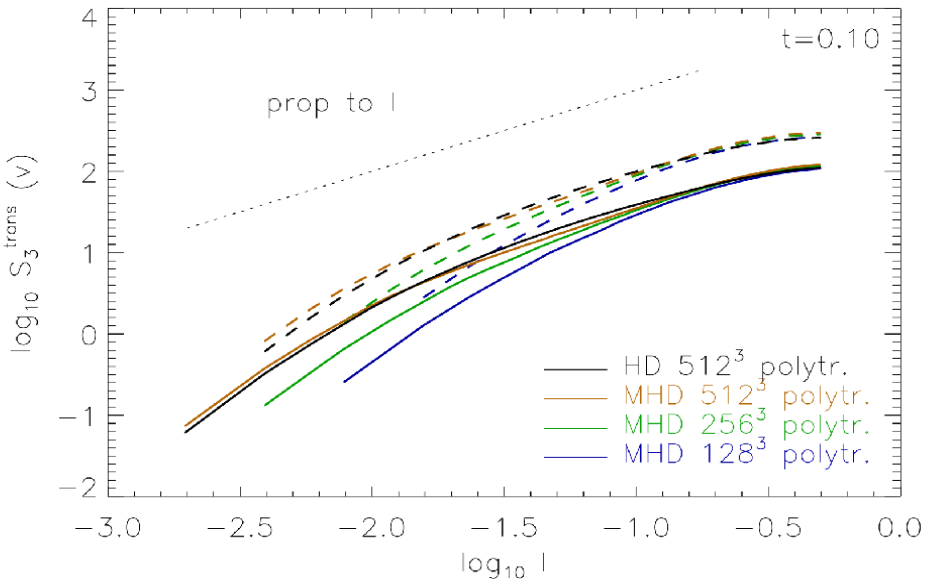
FLASH results – resolution study structure functions

t = 0.10

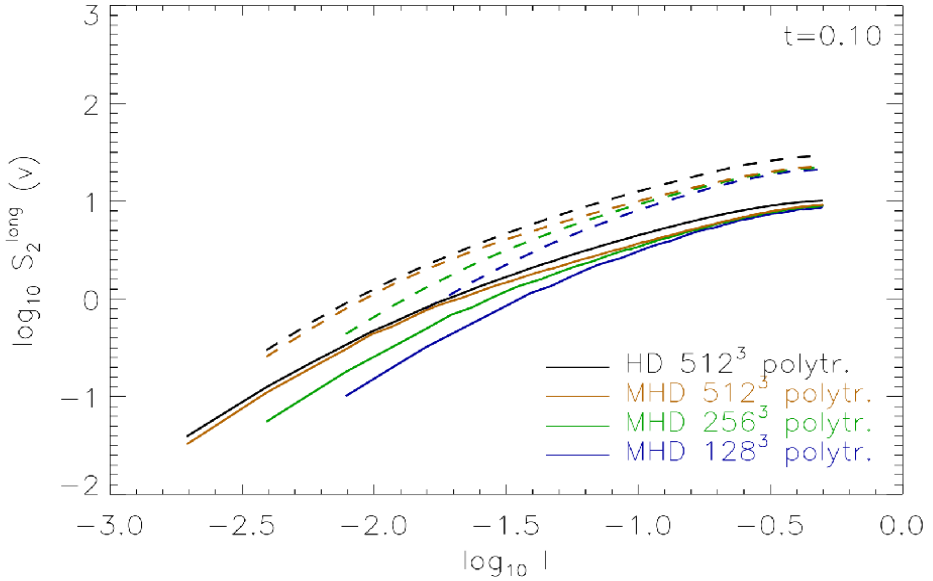
2nd order transversal



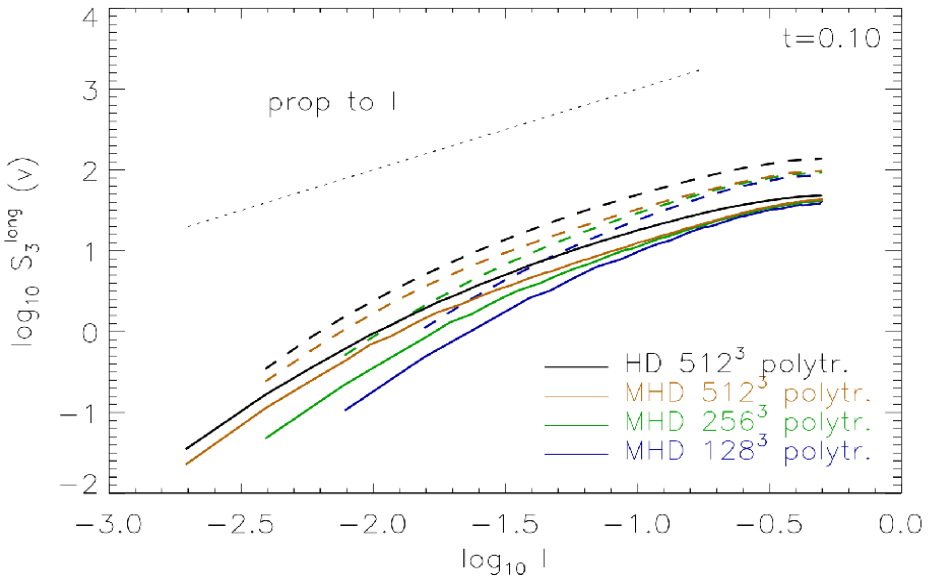
3rd order transversal



2nd order longitudinal



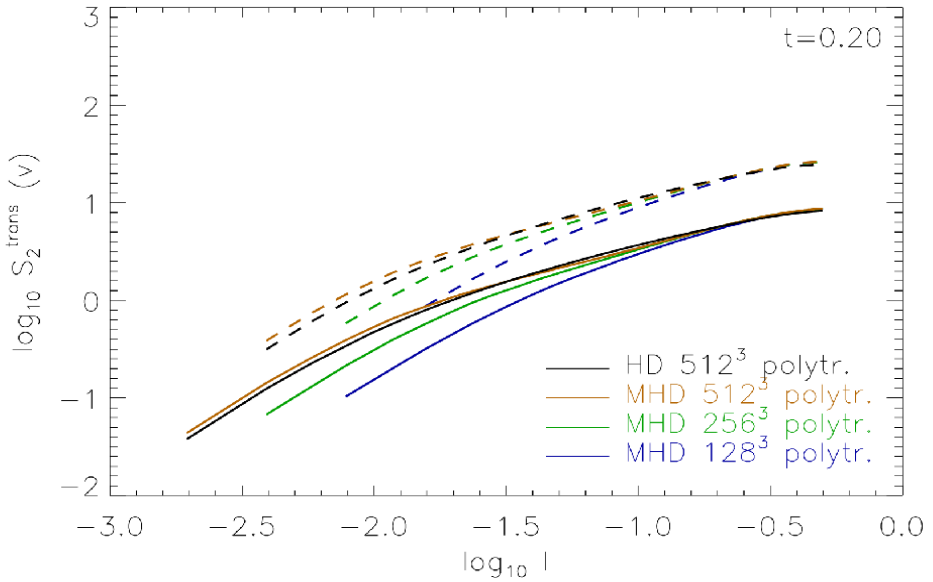
3rd order longitudinal



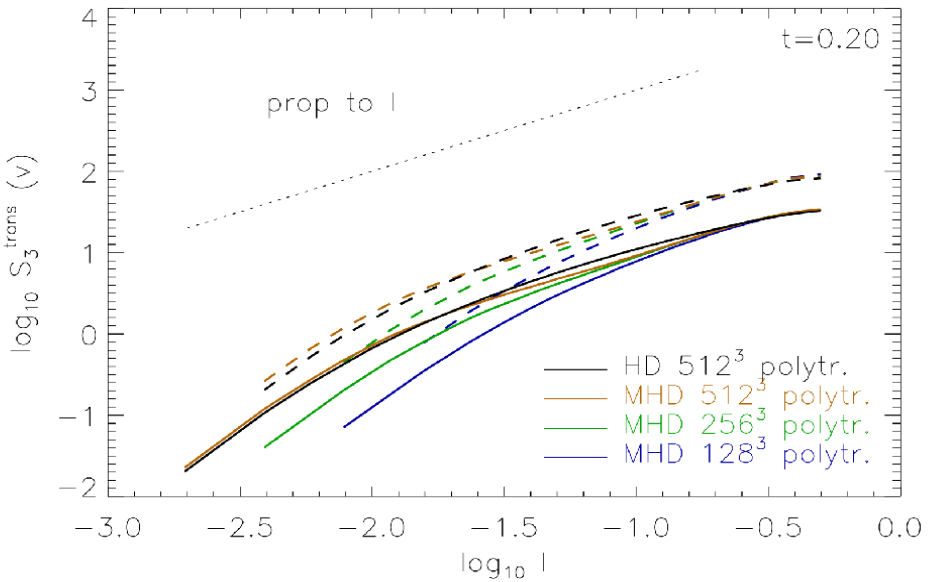
FLASH results – resolution study structure functions

t = 0.20

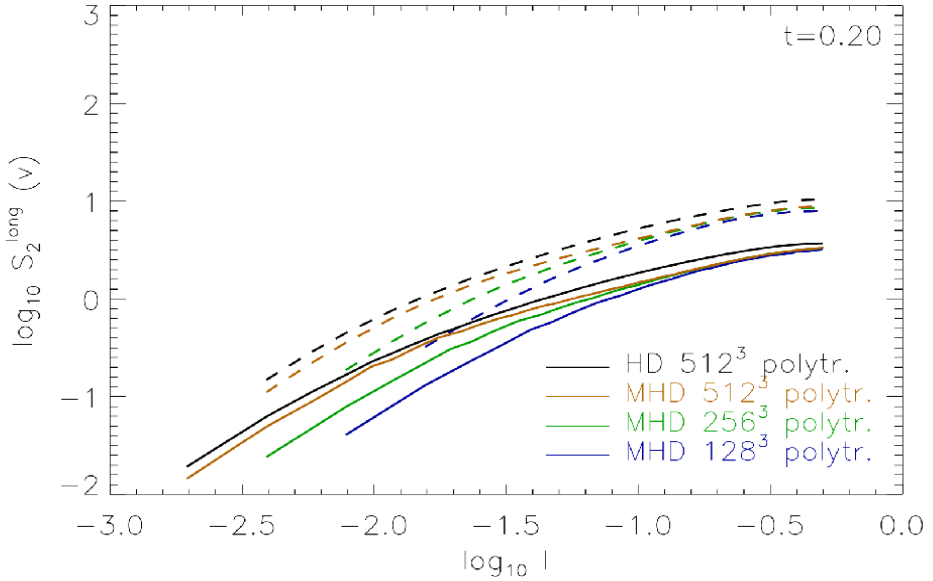
2nd order transversal



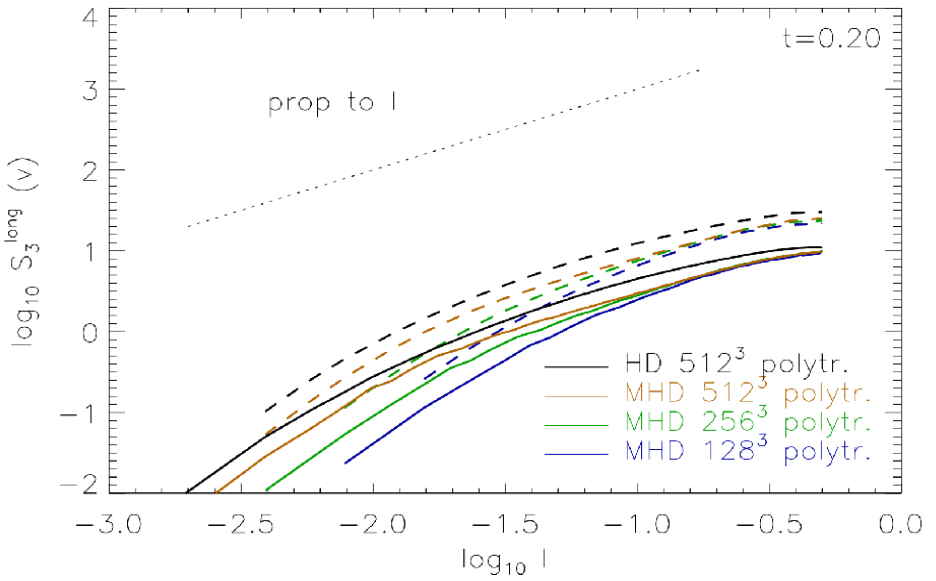
3rd order transversal



2nd order longitudinal



3rd order longitudinal



FLASH results – code performance

model	HD 256	HD 256 poly	HD 512 poly	HD 1024 poly	MHD 128 poly	MHD 256 poly	MHD 512 poly
cputime total [h]	19	20	328	8264	20	550	15389
#cpuh/#cpuh(HD256)	0.95	1	16.4	413	1.00	27.5	769
#cpuh/#cpuh(HD512)	0.06	0.06	1	25.2	0.06	1.68	46.9
num cycles	334	343	693	1430	1631	6176	20697
cputime/cell/cycle [μs]	12.2	12.5	12.7	19.4	21.0	19.1	19.9
num cpus used	8	8	64	512	8	16	128

architectures used:
- SGI Altix 4700 Intel Itanium (LRZ Garching)
- AIX IBM Power 5 (CASPUR, Italy)

all numbers were corrected to be representative for SGI Altix Intel Itanium architecture used at the HLRB II at Leibniz Rechenzentrum Garching (LRZ)
(conversion factor: #cpuh(@Intel)=1.05*#cpuh(@IBM))