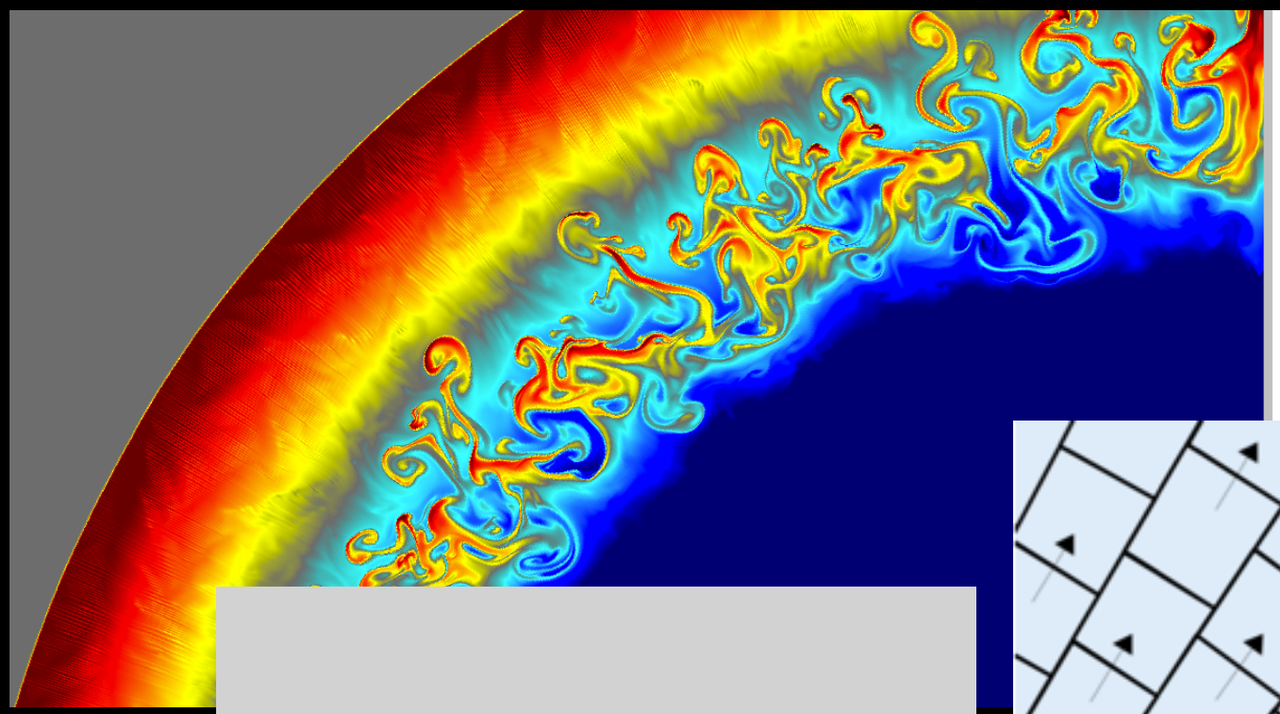
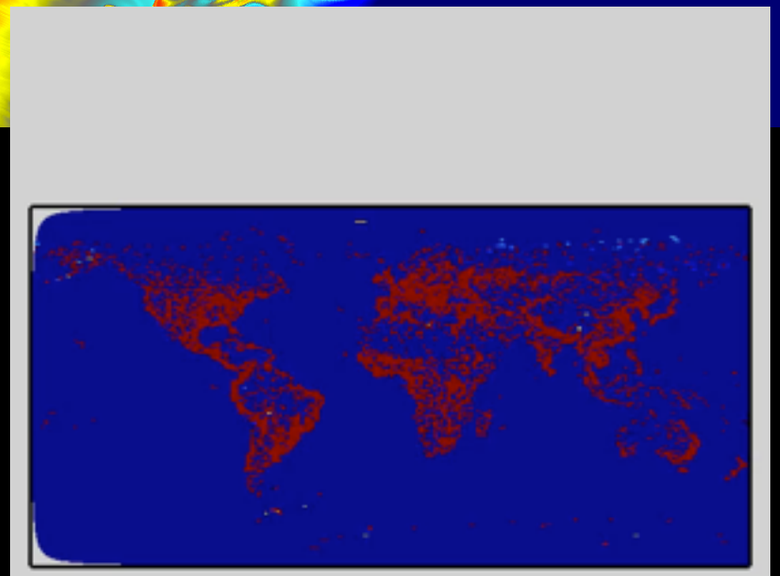
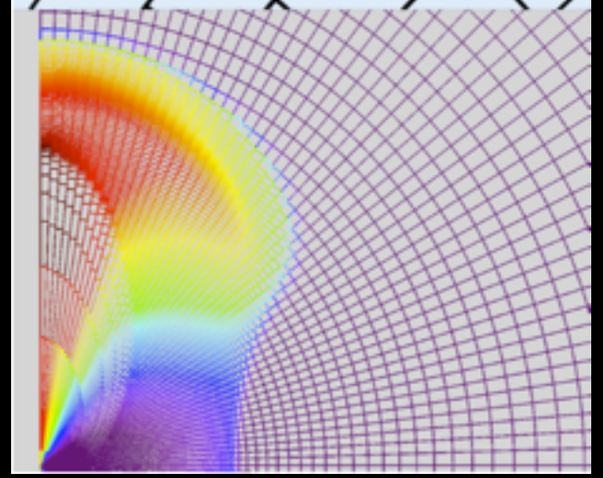
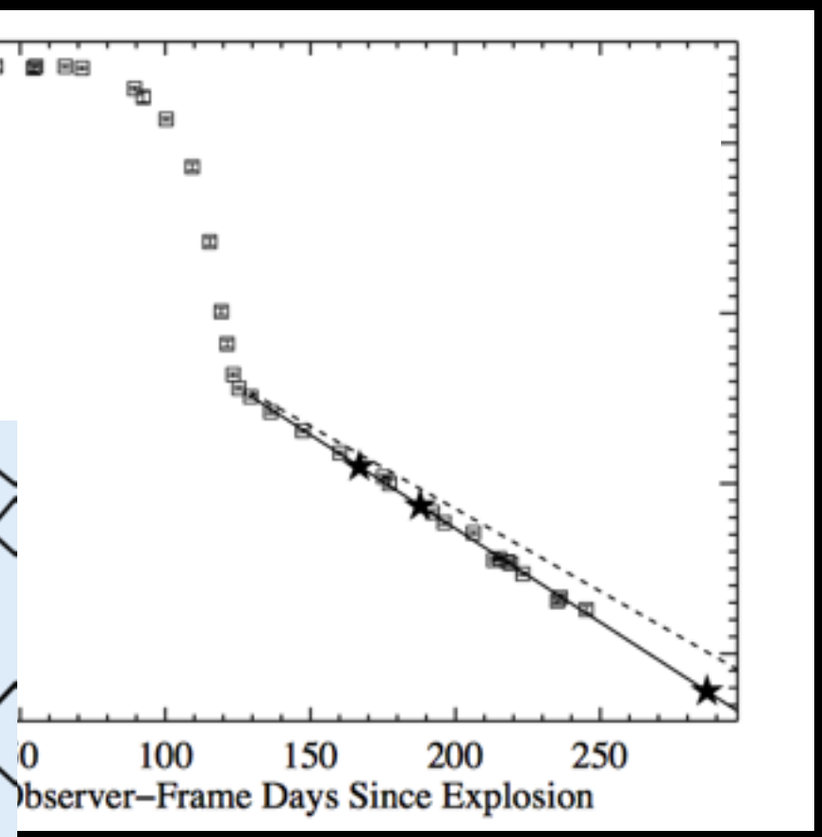
Modeling the 3D effects of Rayleigh-Taylor Instability in Type IIp Supernovae









Paul Duffell
TAC Fellow, UC Berkeley

with Lars Bildsten and Bill Paxton

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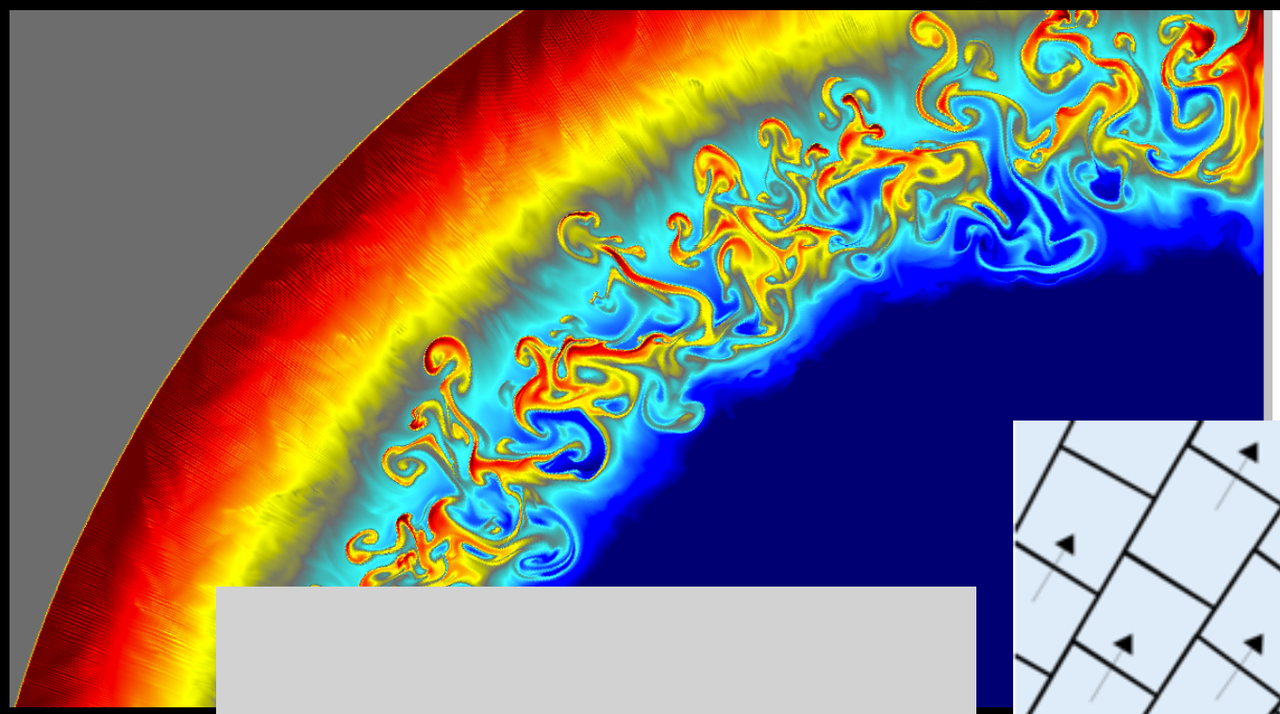

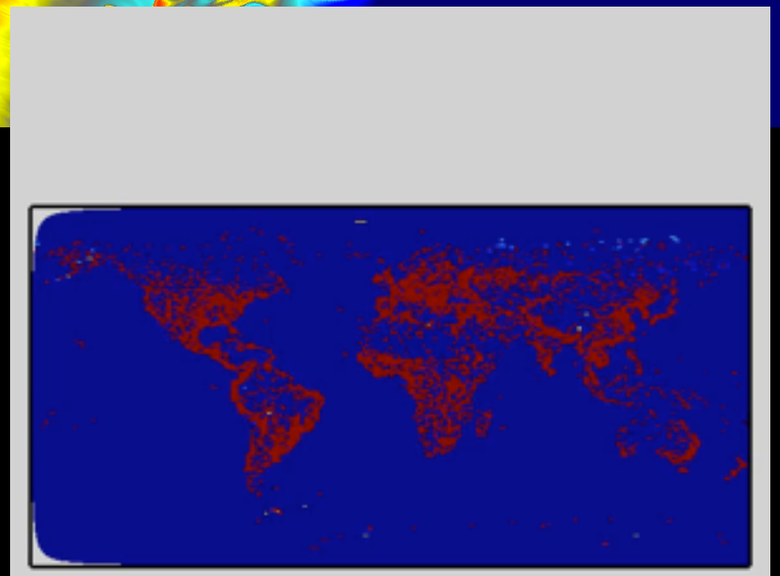

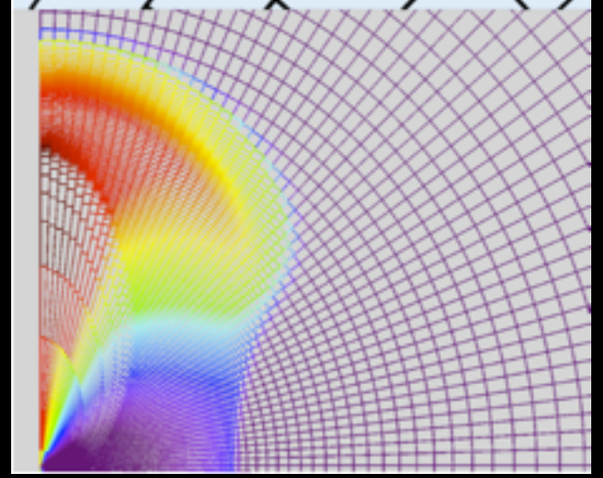

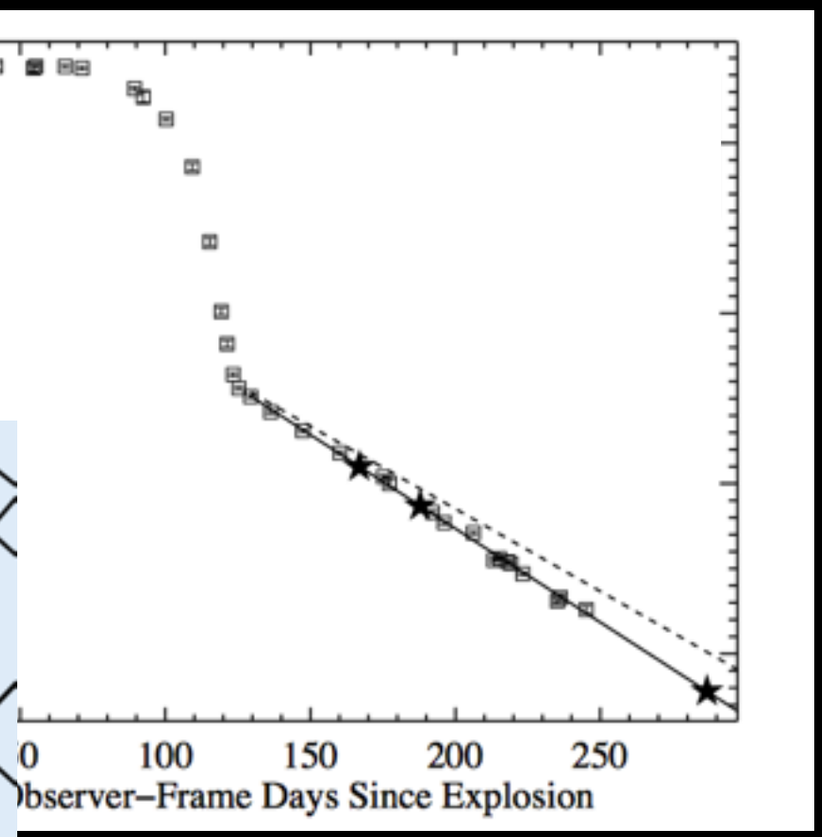

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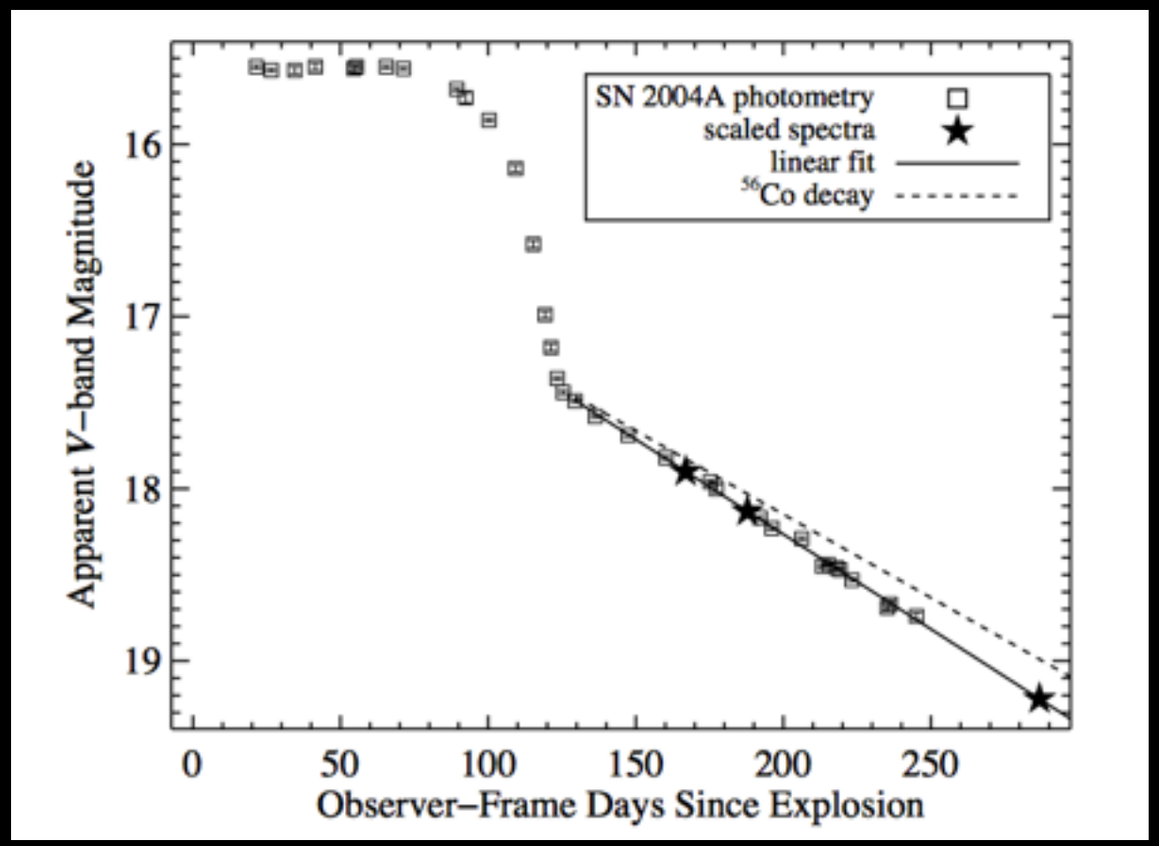
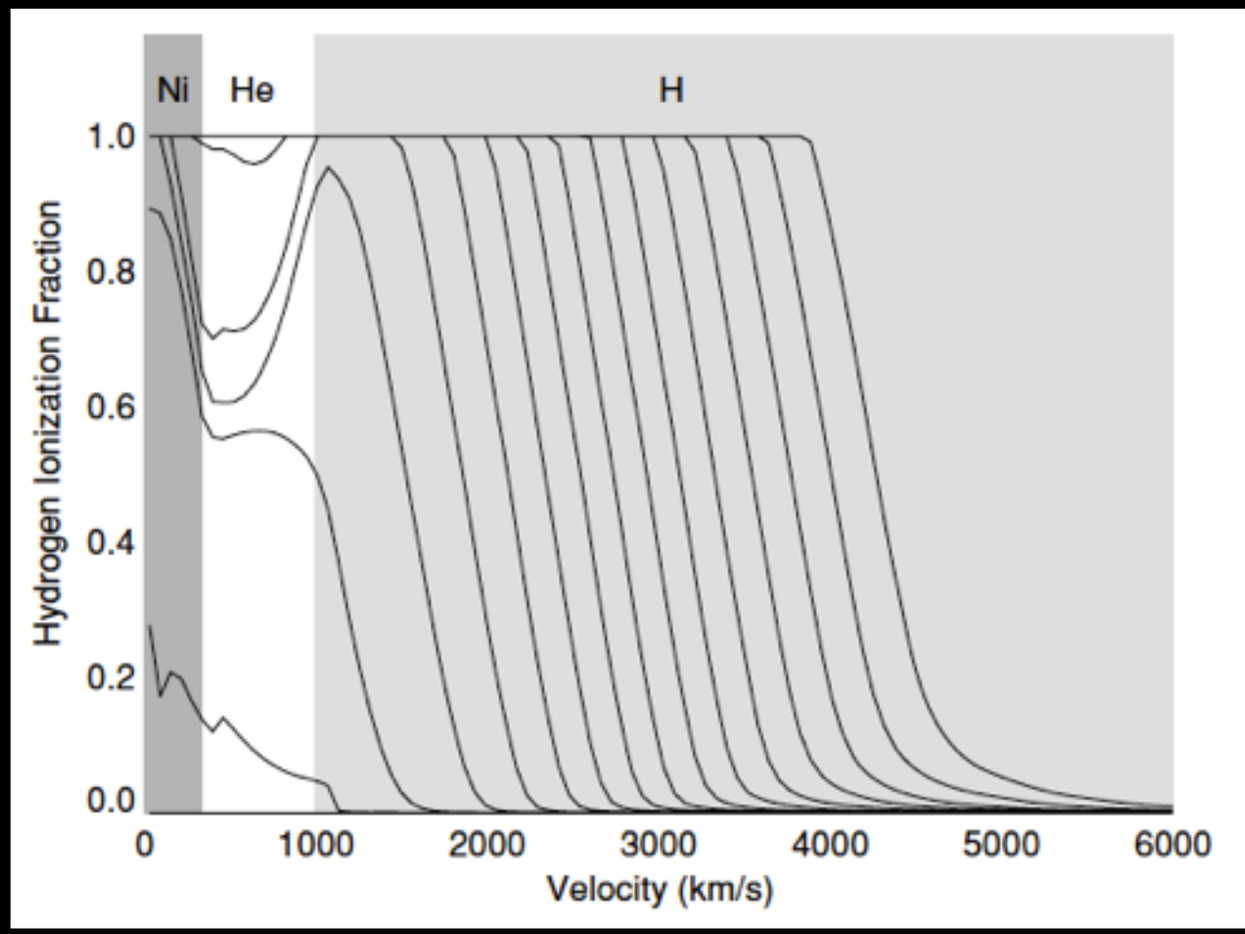
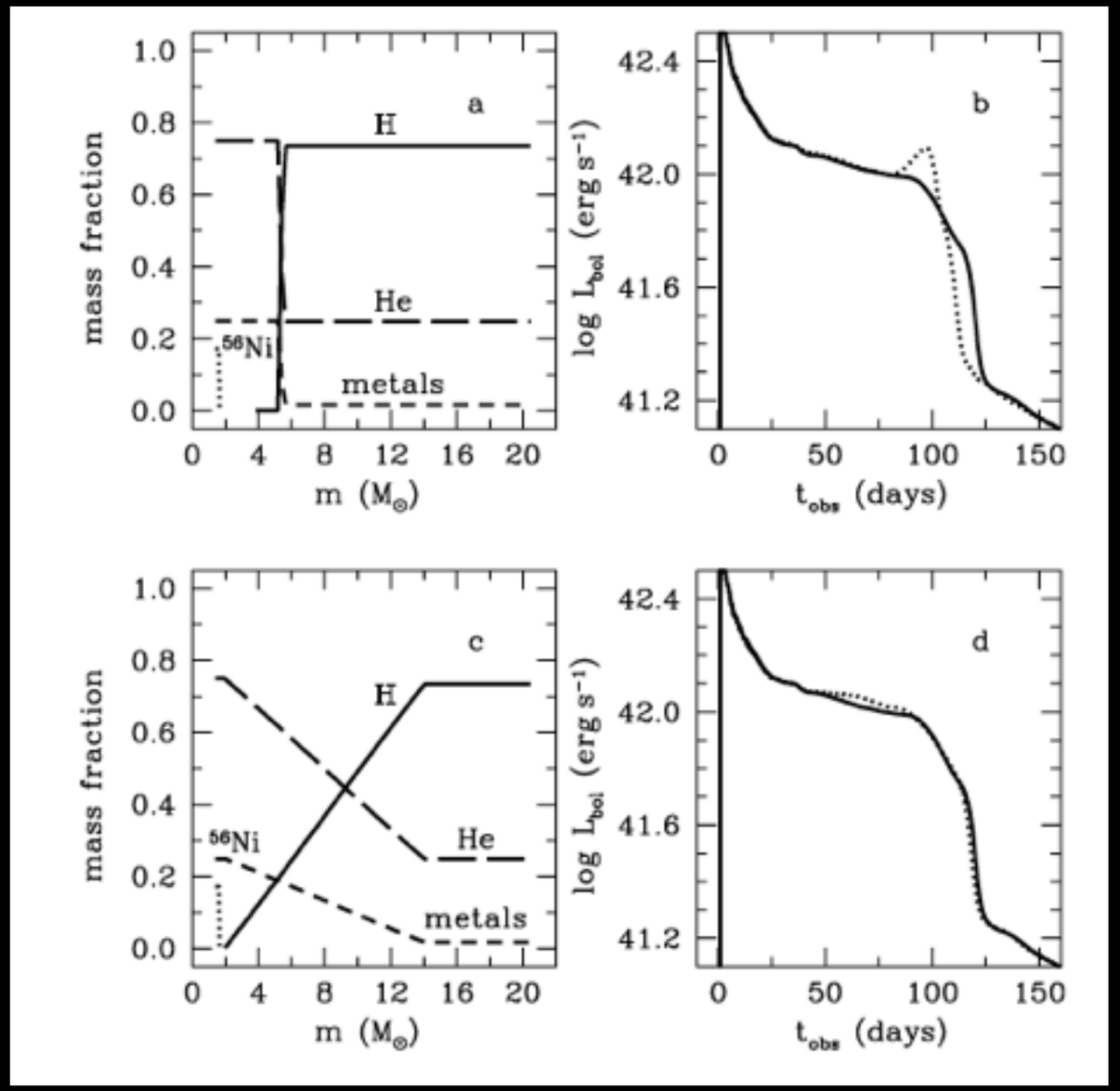


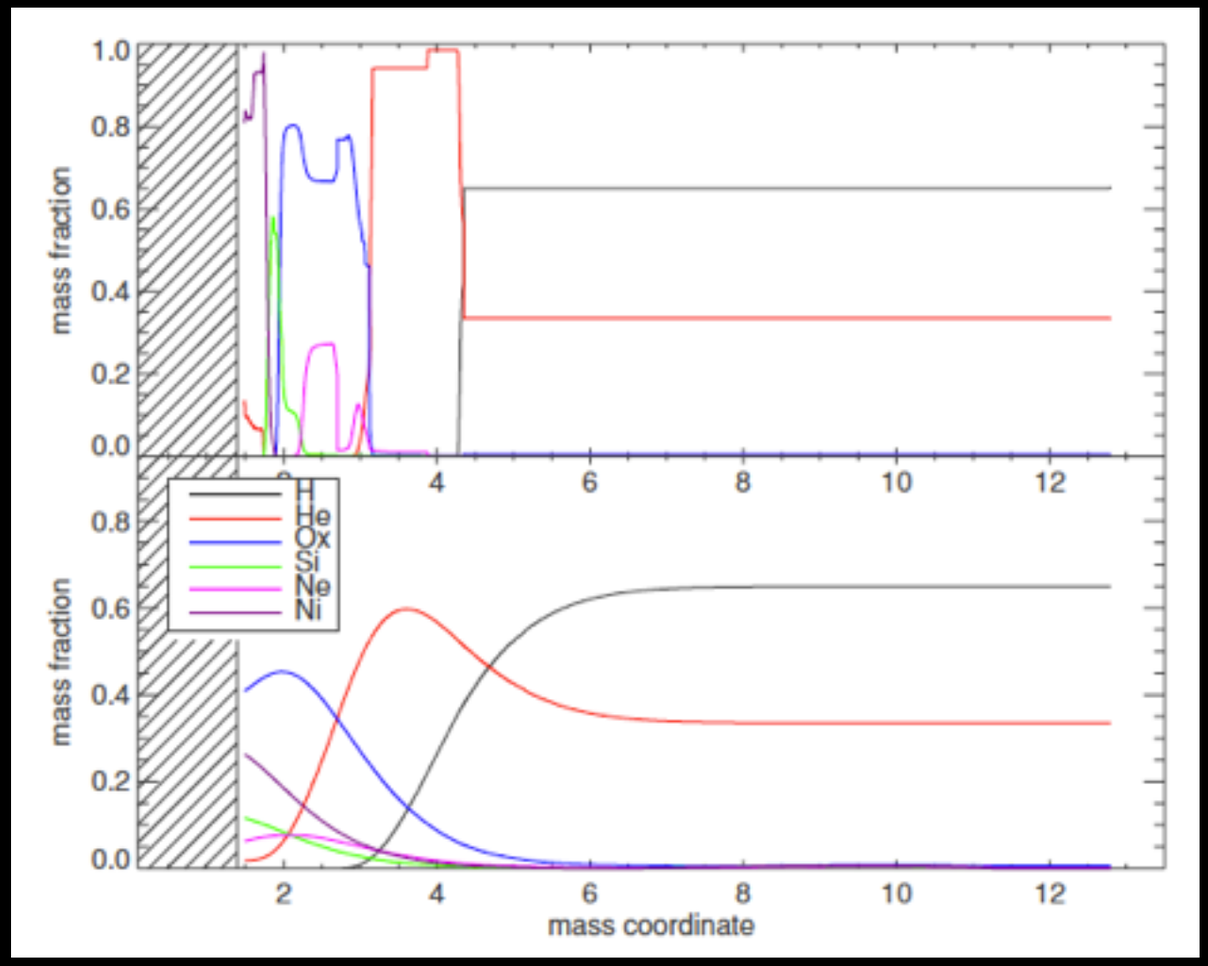
Silverman et al (2016)



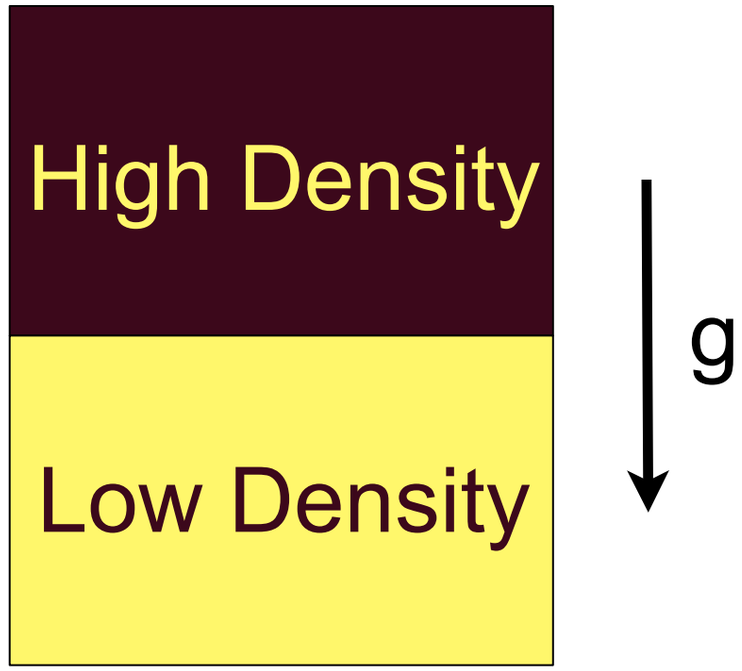
Kasen & Woosley (2009)

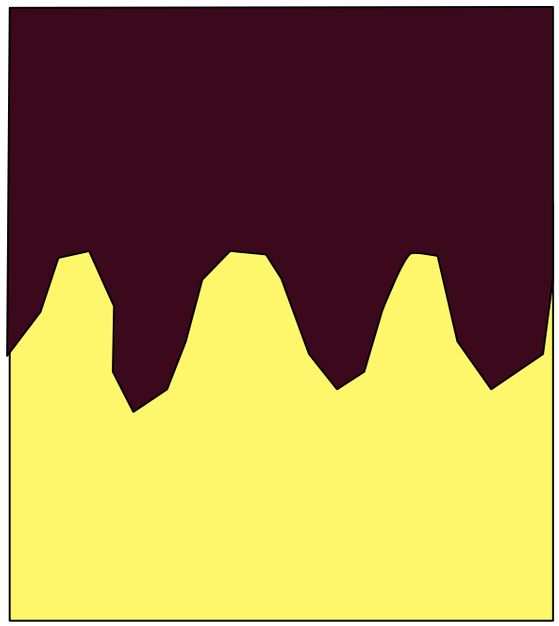


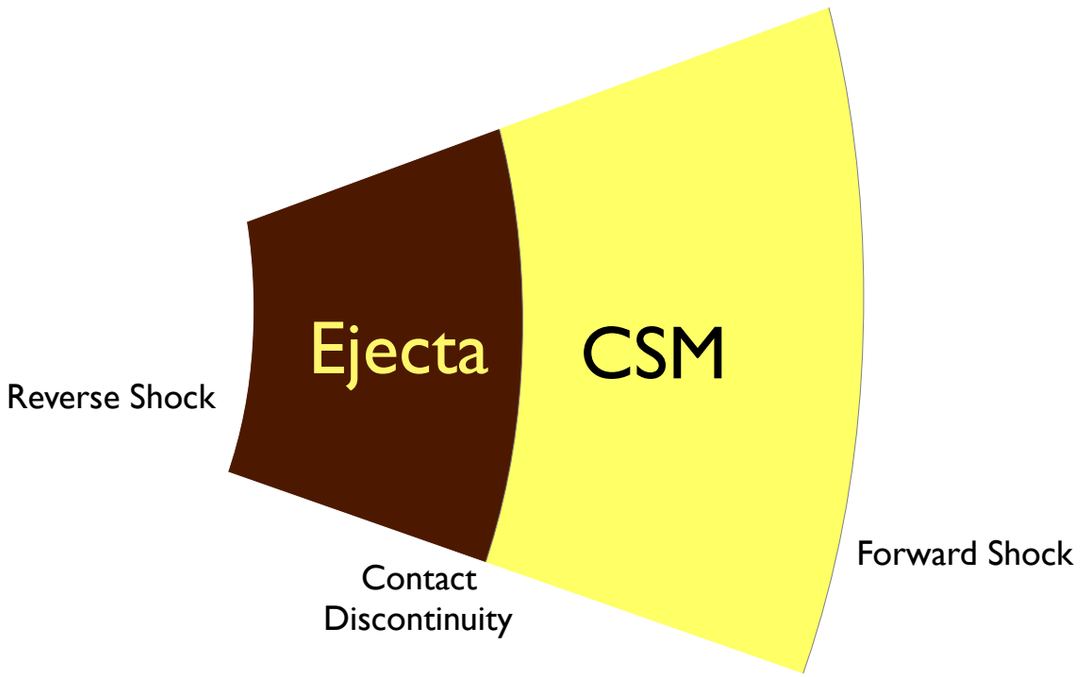
Utrobin (2007)

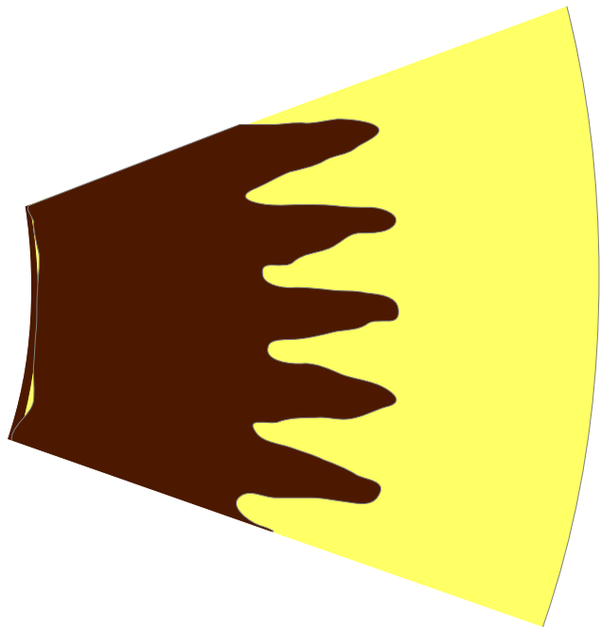


Kasen & Woosley (2009)


High Density
Low Density
g



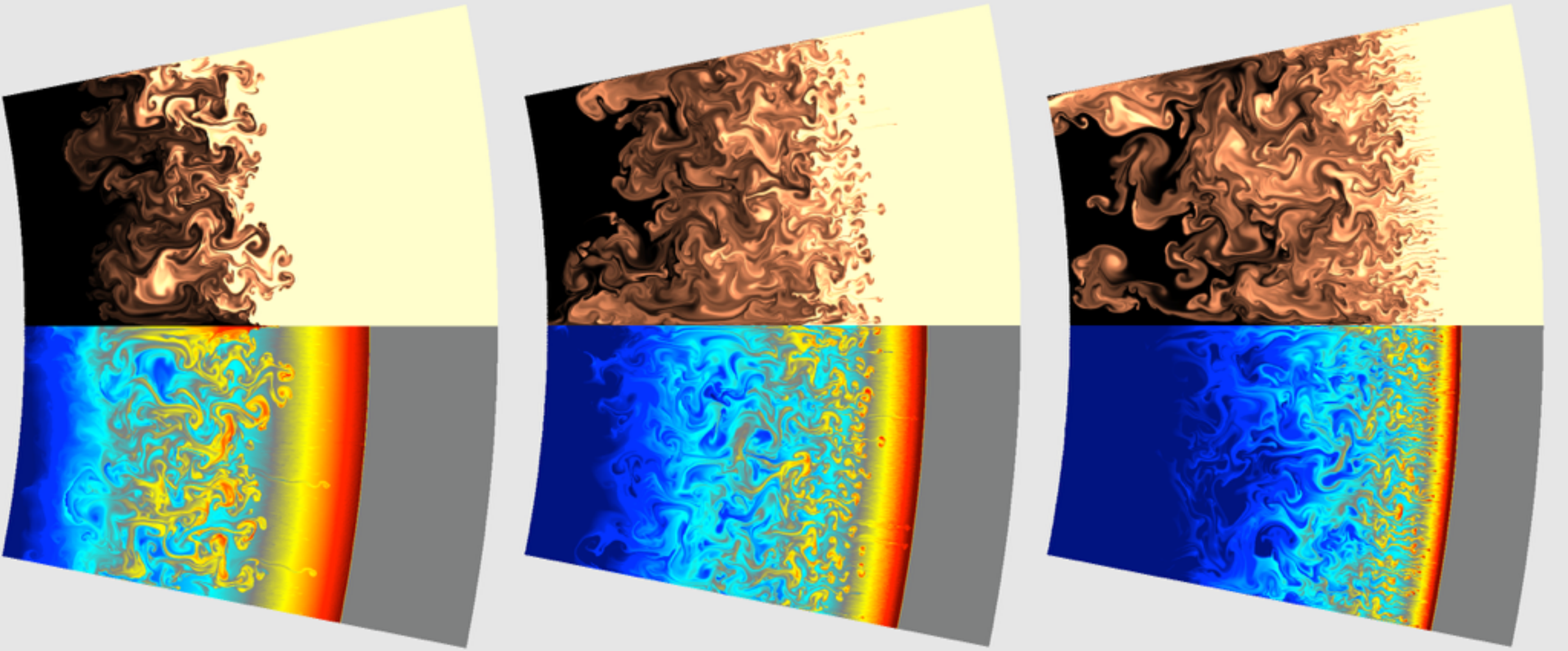

Reverse Shock
Ejecta
CSM
Forward Shock
Contact
Discontinuity



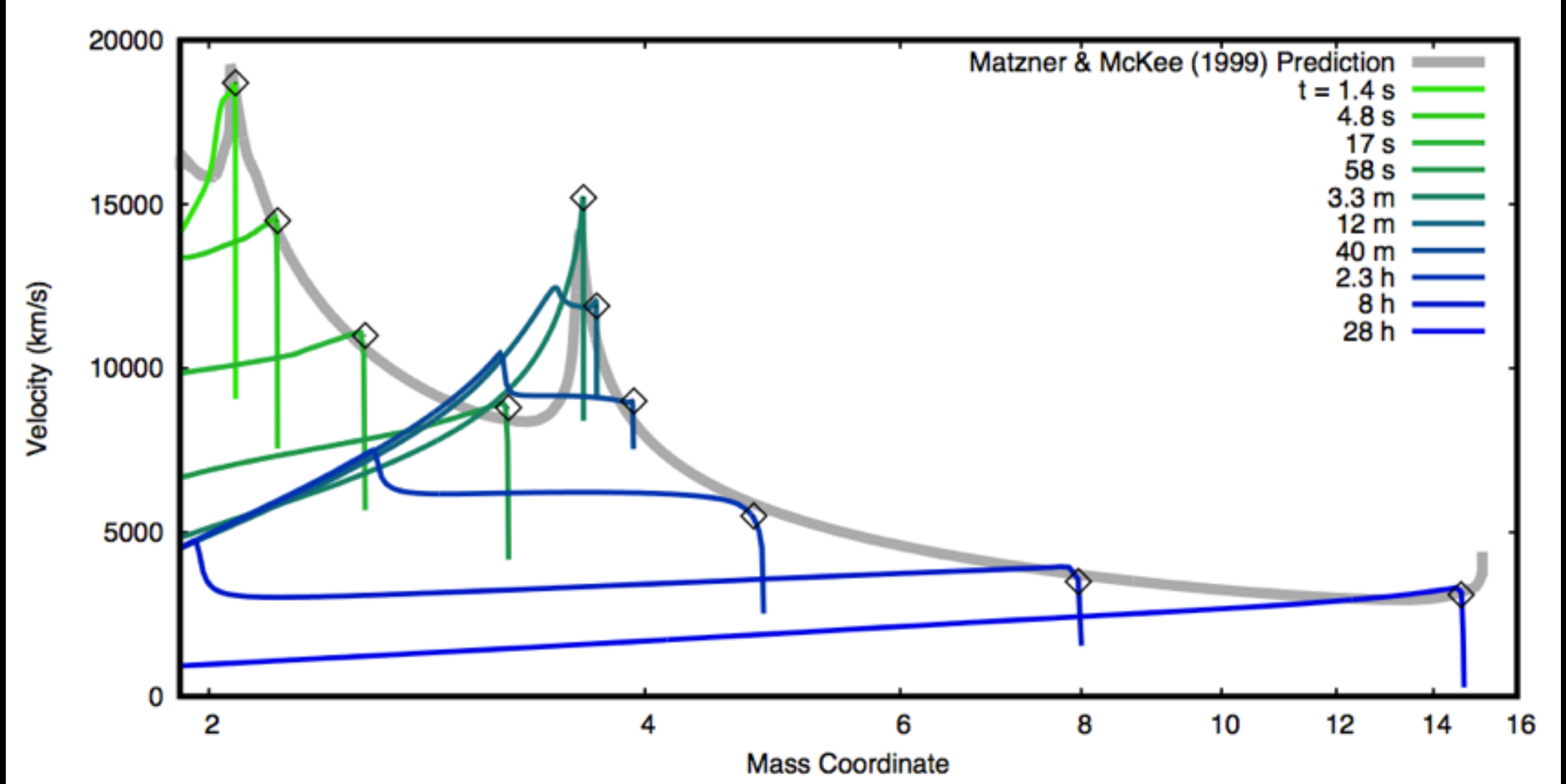
Lorentz Factor = 10

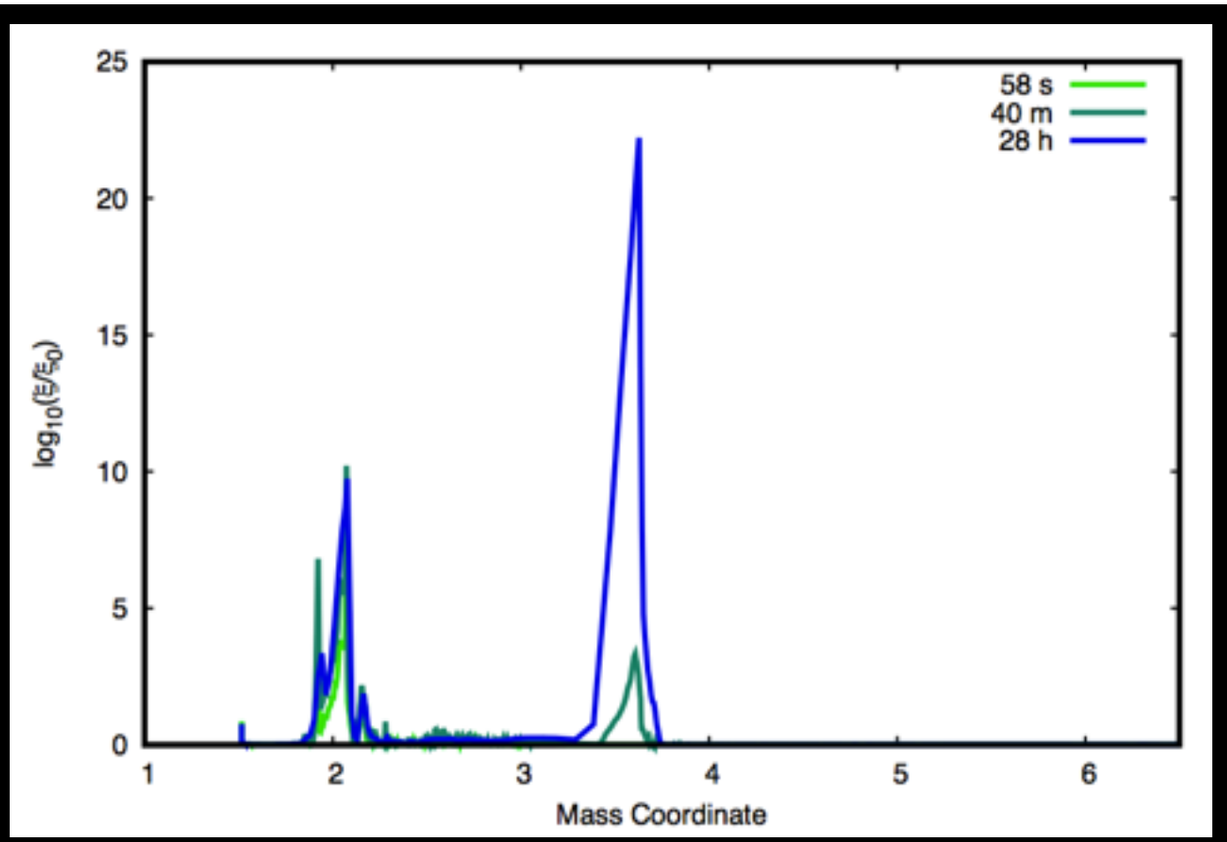
30

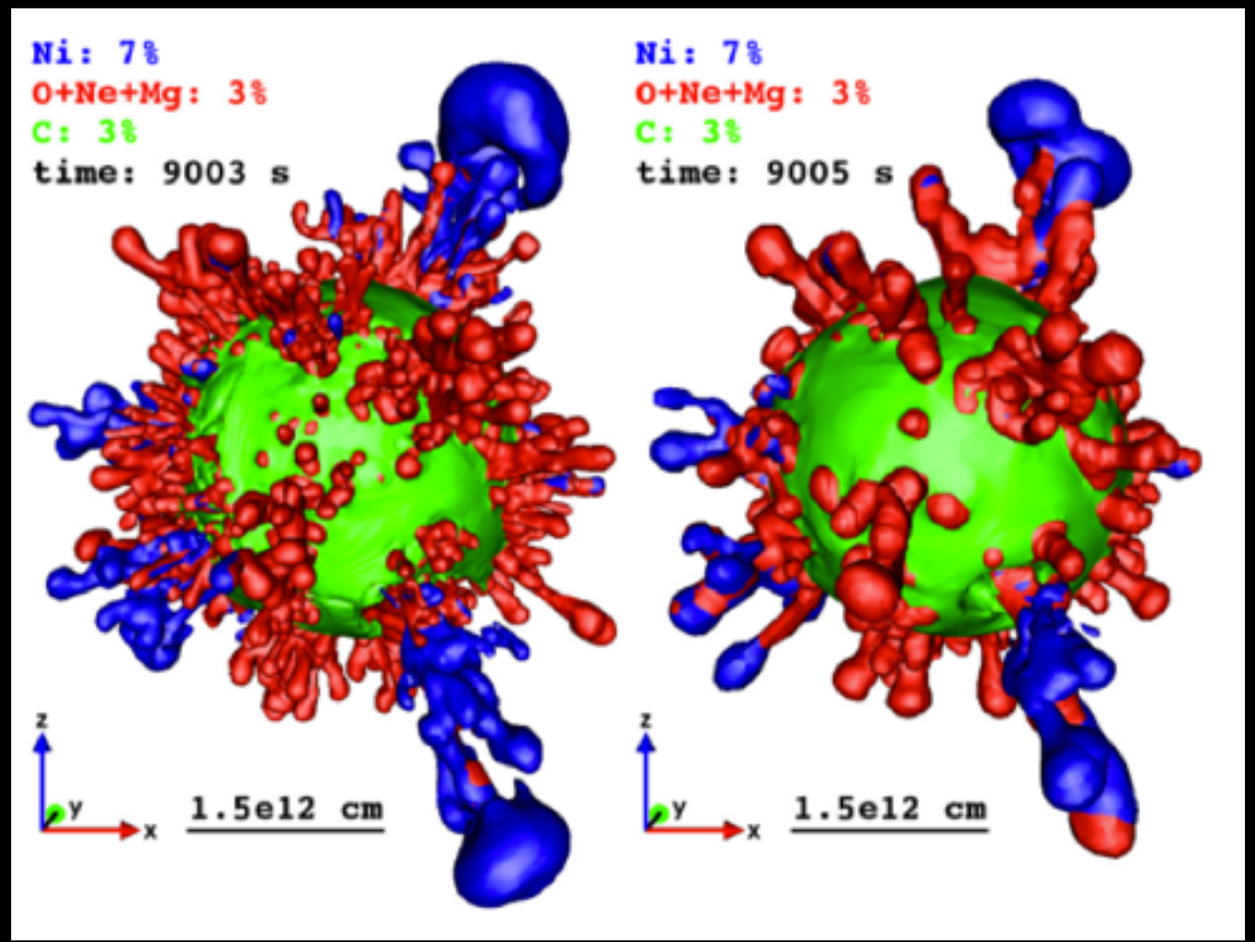
100



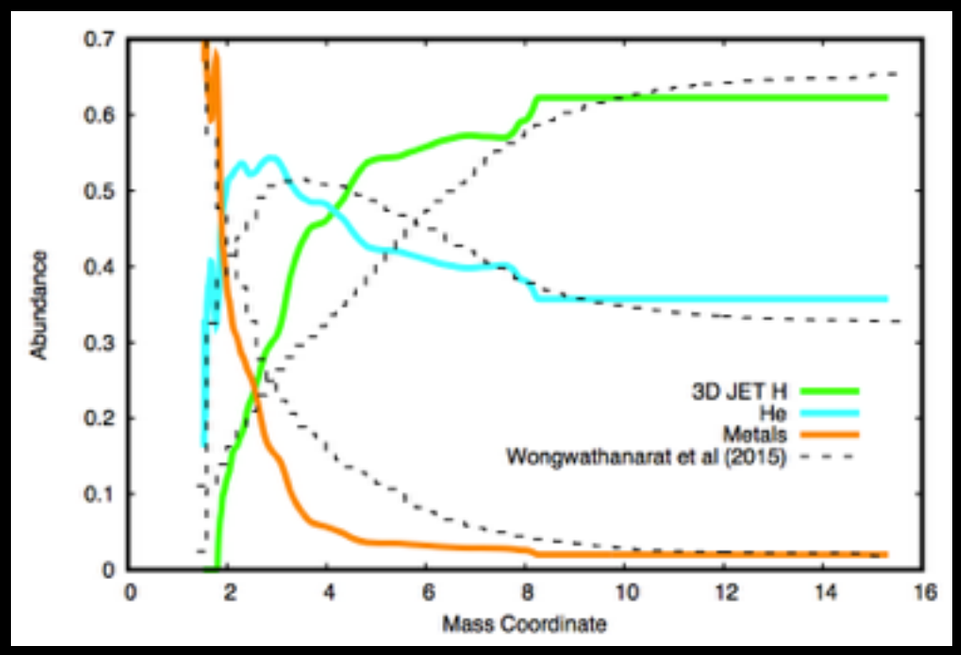
Duffell & MacFadyen (2013)

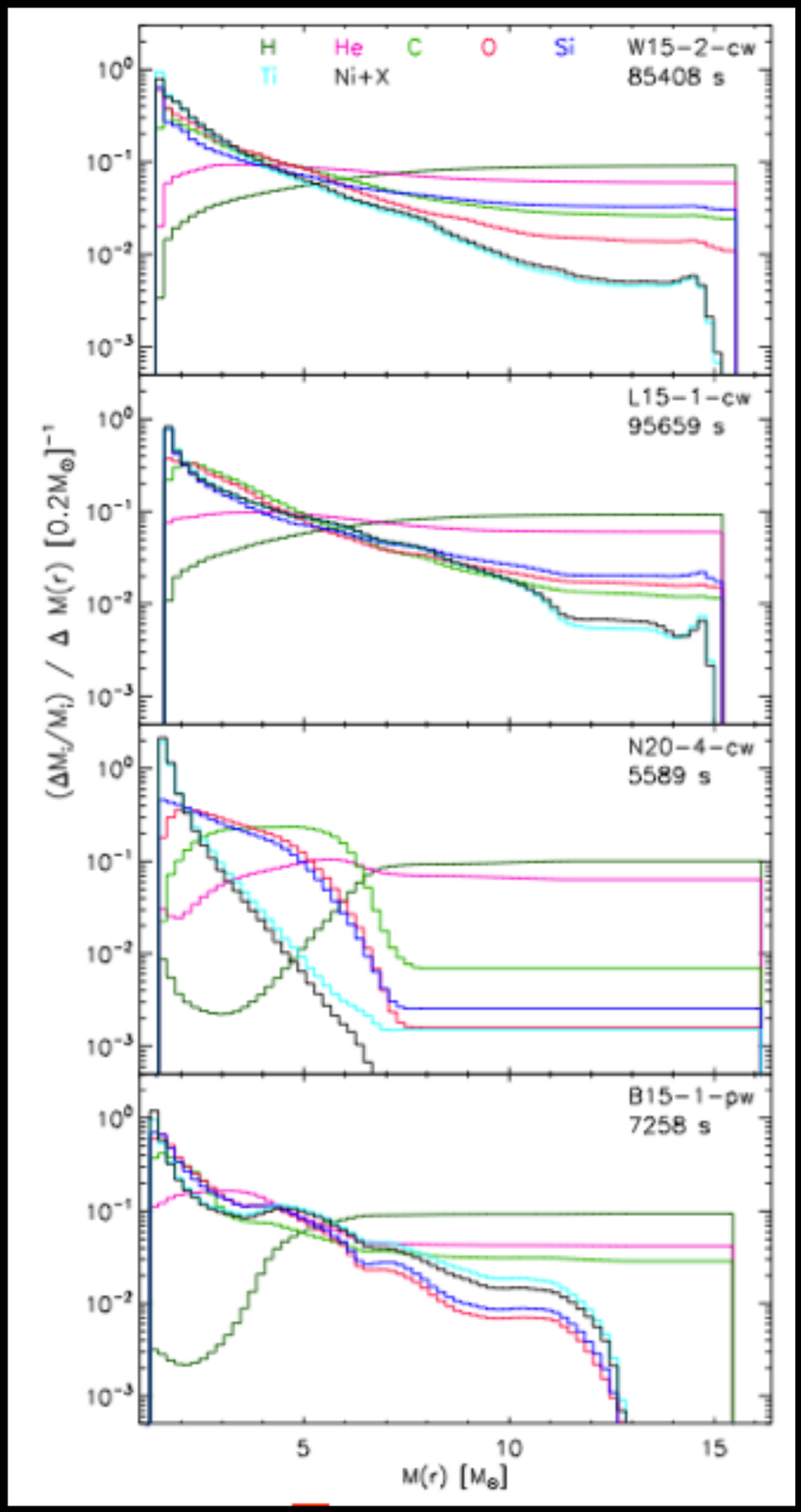

Matzner & McKee (1999) Prediction
t = 1.4 s
4.8 s
17 s
58 s
3.3 m
12 m
40 m
2.3 h
8 h
28 h
Velocity (km/s)
20000
15000
10000
5000
0
2
4
6
8
10
12
14
16
Mass Coordinate

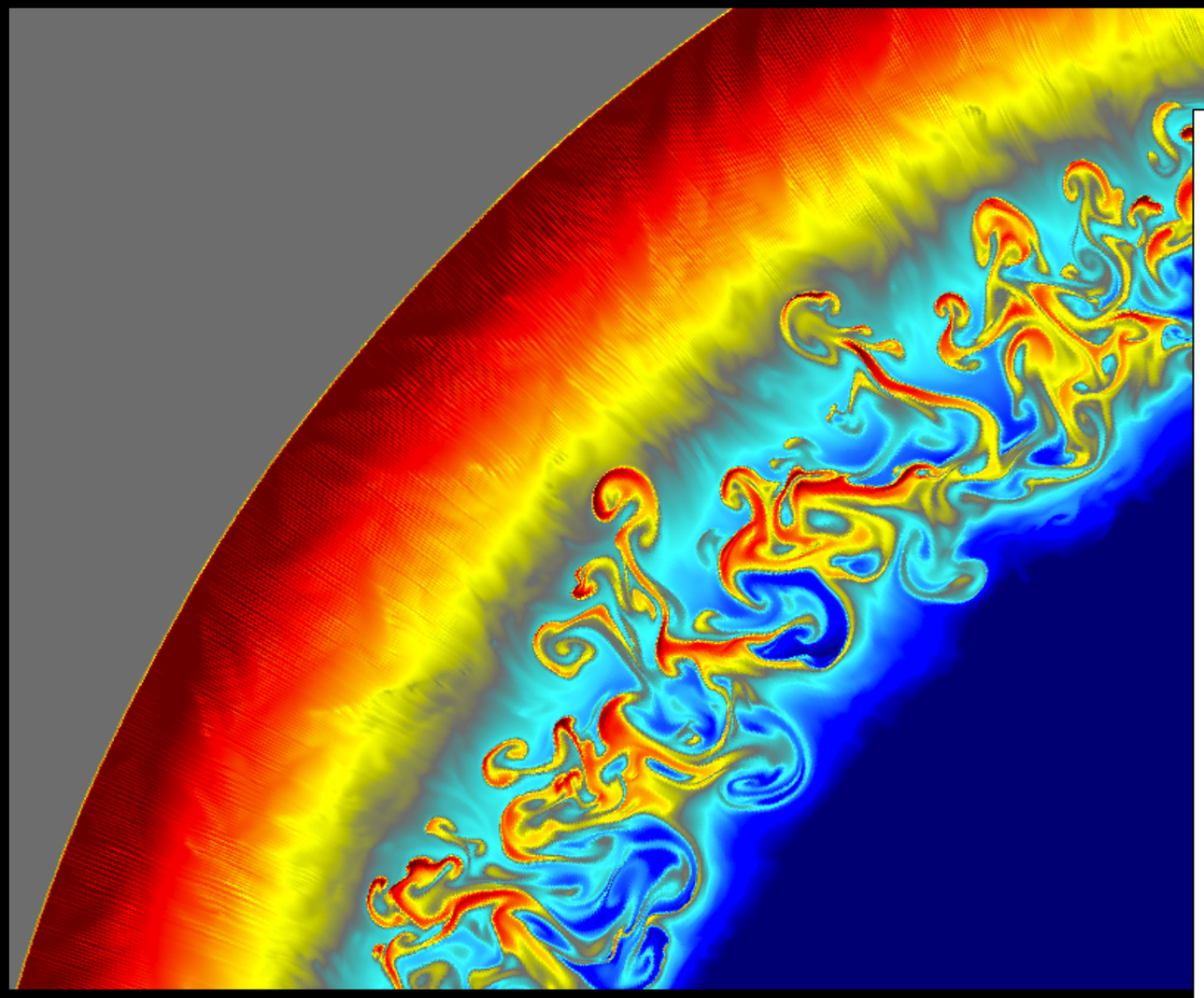

58 s
40 m
28 h
log10(E/E0)
25
20
15
10
5
0
1
2
3
4
5
6
Mass Coordinate

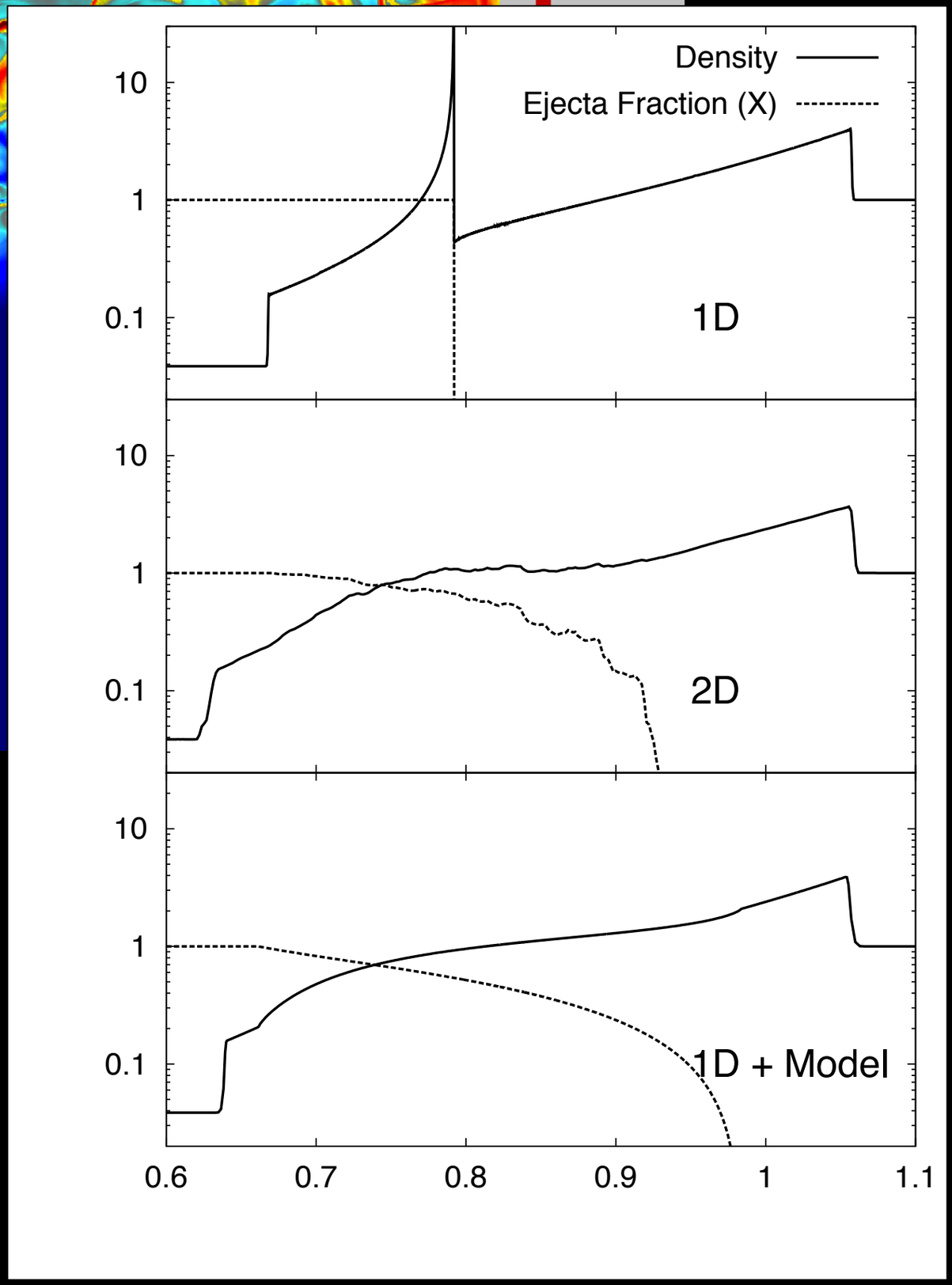


Wongwathanarat et al (2015)









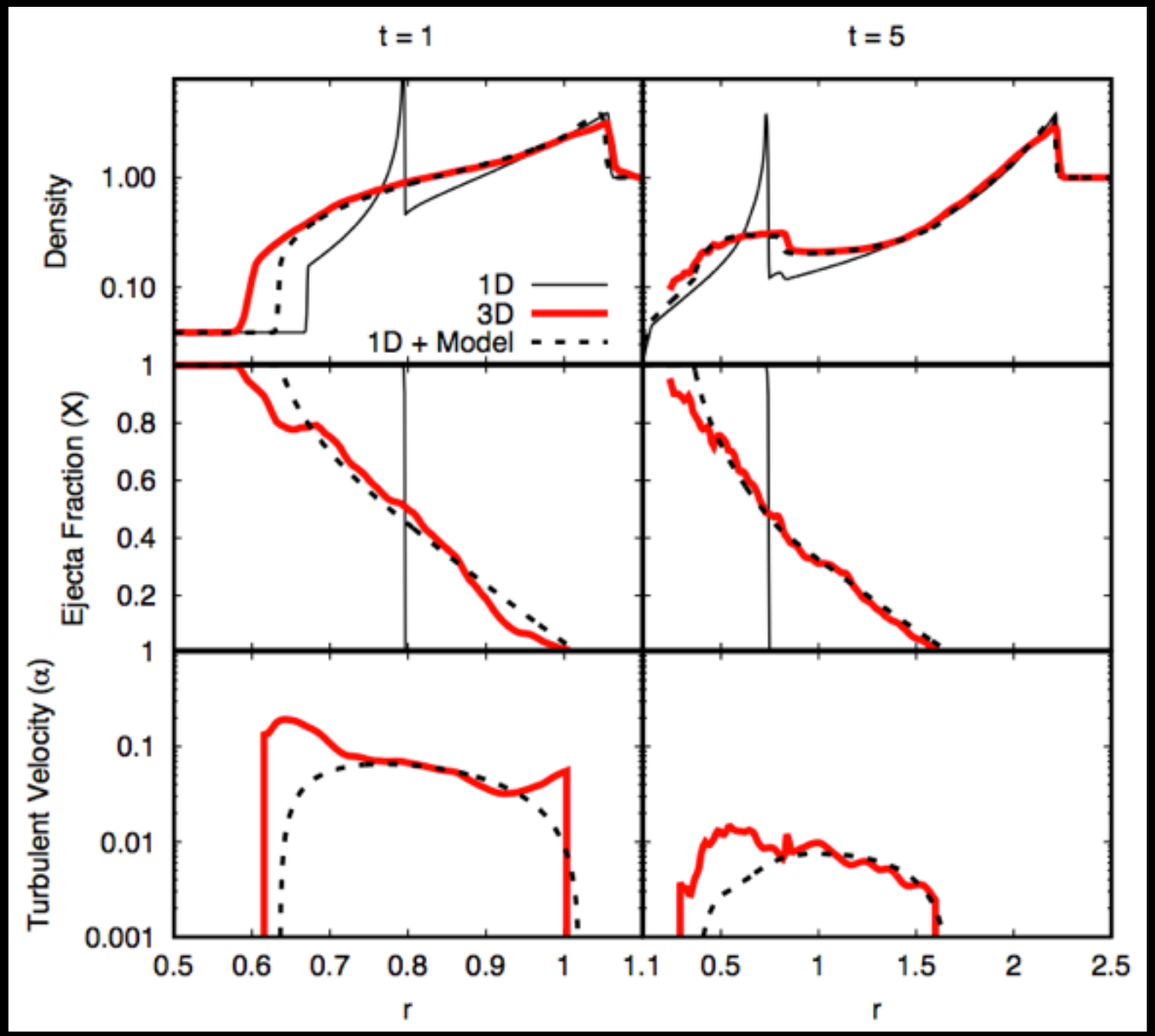
$$\partial_t(\rho) + r^{-2}(r^2(\rho v + \eta\rho'))' = 0$$

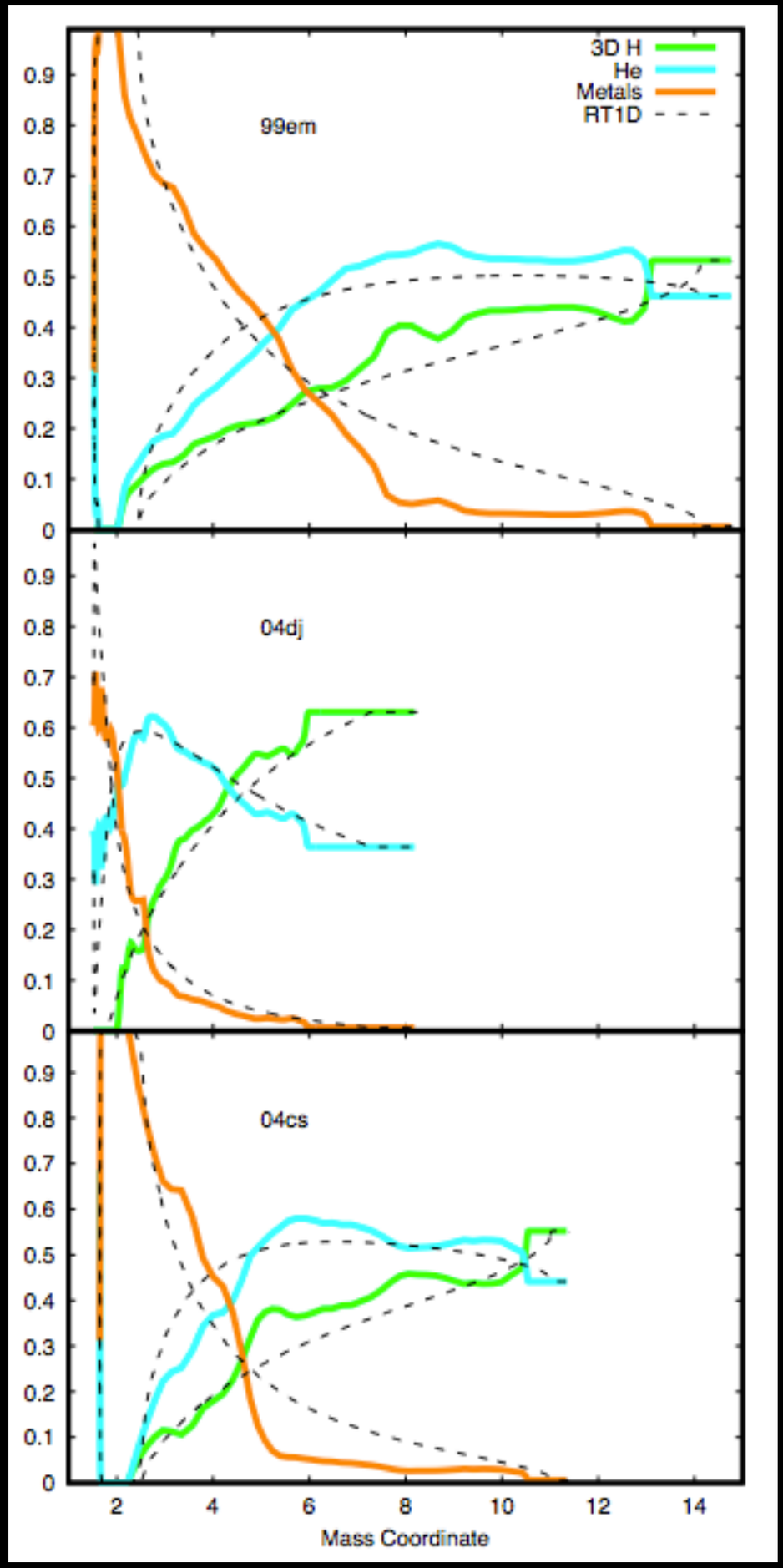
$$\partial_t(\rho v) + r^{-2}(r^2(\rho v^2 + P + \eta(\rho v)'))' = 2P/r$$

$$\partial_t(\epsilon_{tot}) + r^{-2}(r^2((\epsilon_{tot} + P)v + \eta\epsilon'_{tot}))' = 0$$

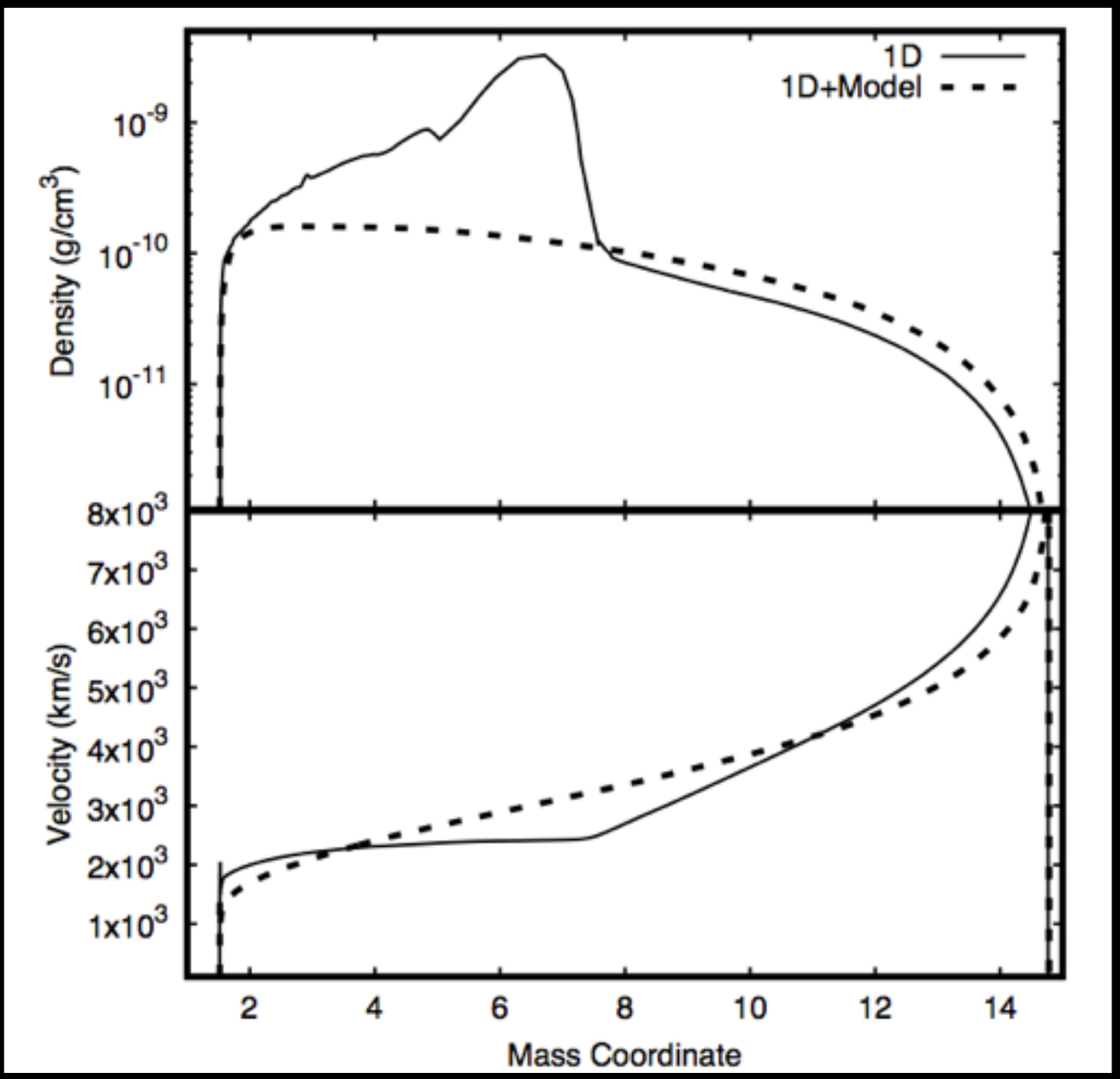
$$\partial_t(\rho\alpha) + r^{-2}(r^2(\rho\alpha v + \eta(\rho\alpha)'))' = S_\alpha$$

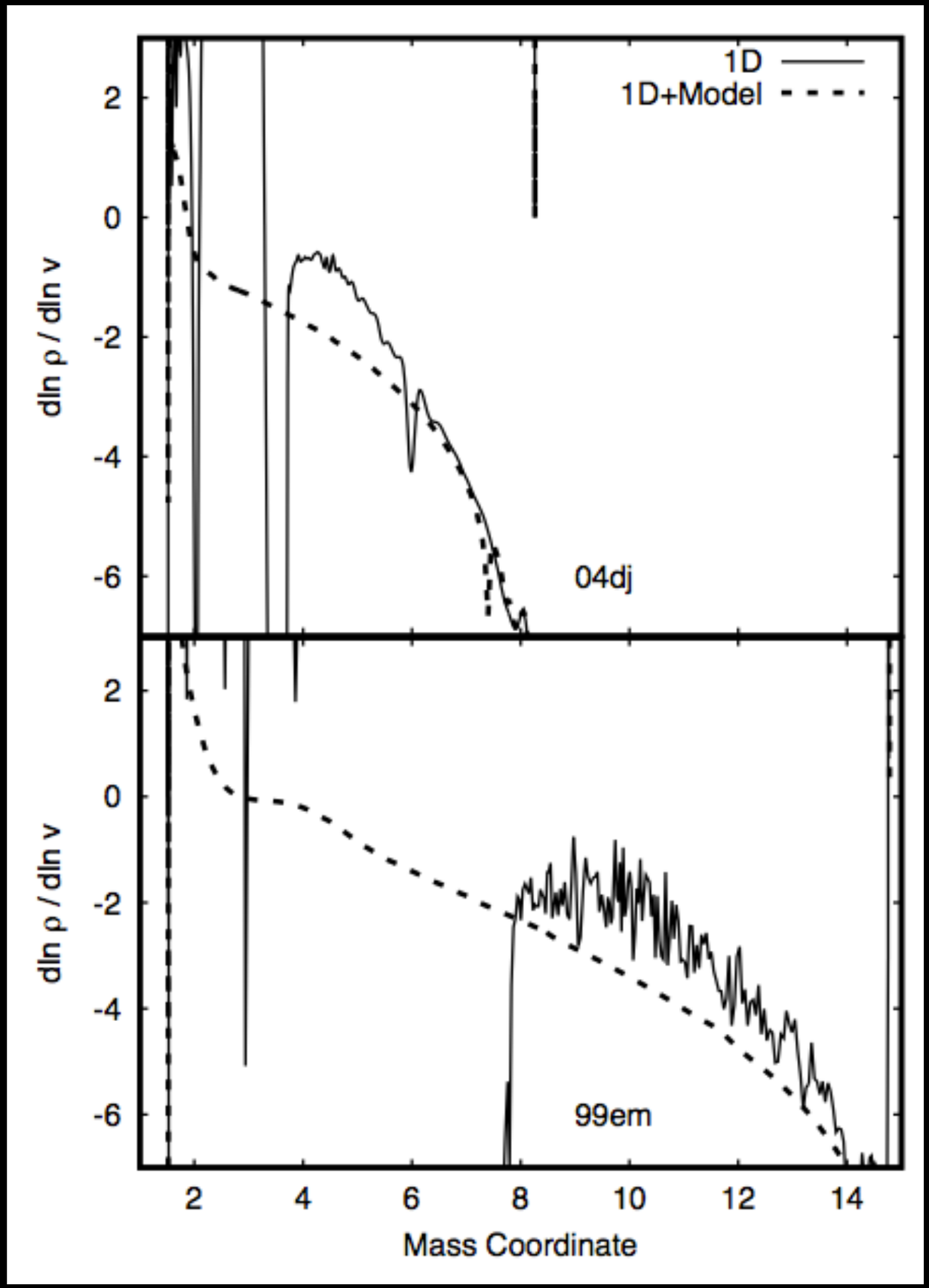
Duffell (2016) (see also Gull 1973)

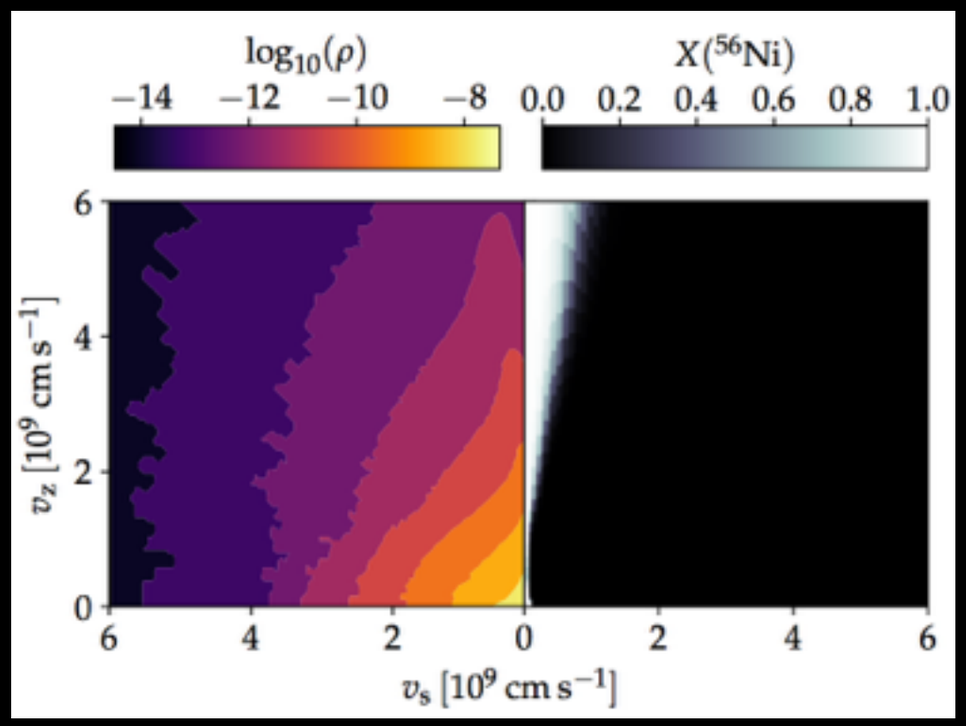


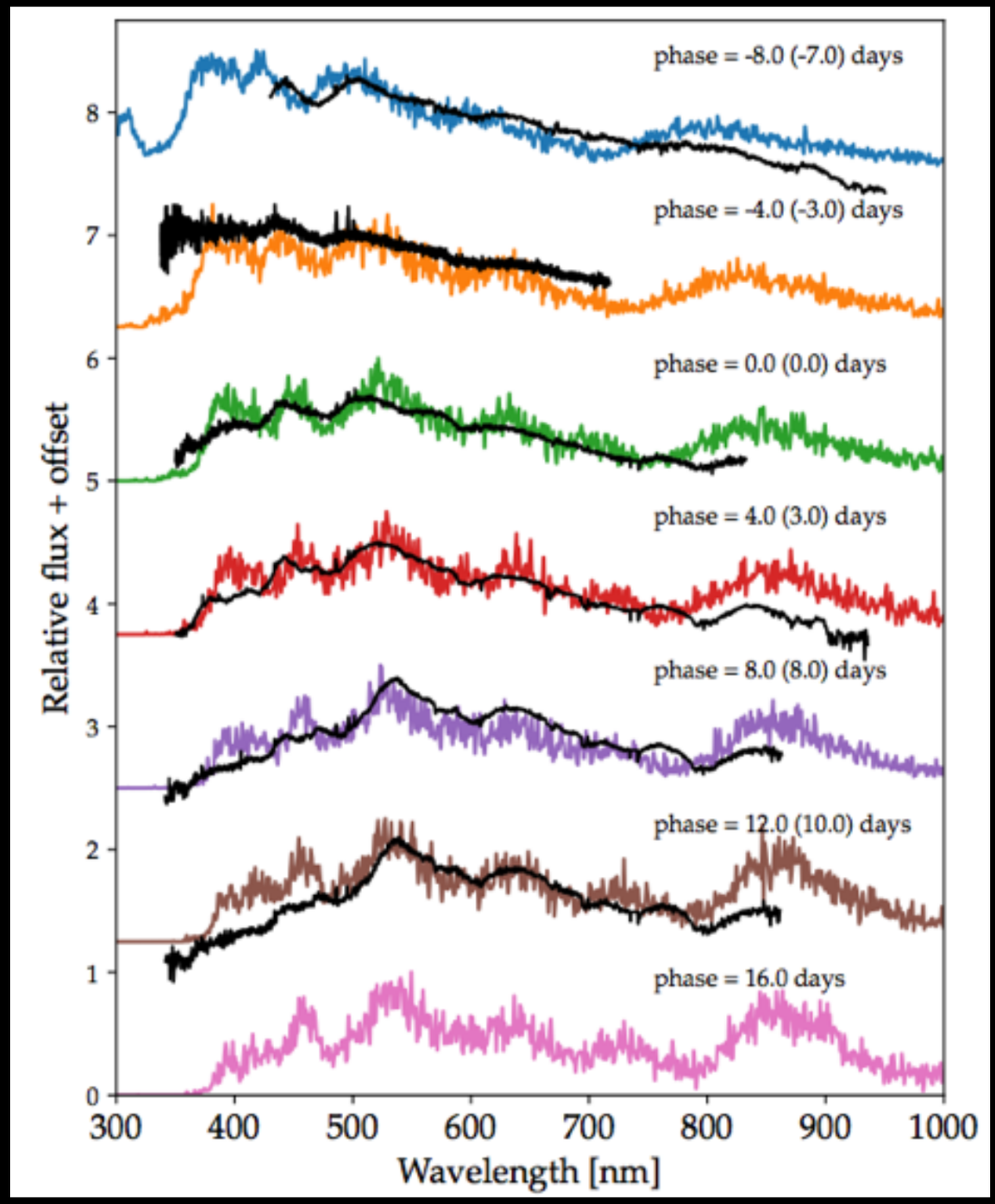


github.com/duffell/RT1D


1D
1D+Model
Density (g/cm^3)
10^{-9}
10^{-10}
10^{-11}
Velocity (km/s)
$8x10^3$
$7x10^3$
$6x10^3$
$5x10^3$
$4x10^3$
$3x10^3$
$2x10^3$
$1x10^3$
2
4
6
8
10
12
14
Mass Coordinate


1D
1D+Model
dln ρ / dln v
2
0
-2
-4
-6
04dj
99em
2
4
6
8
10
12
14
Mass Coordinate





(with Jennifer Barnes, Dan Kasen, Yuqian Yu, Maryam Modjaz, and Andrew MacFadyen)