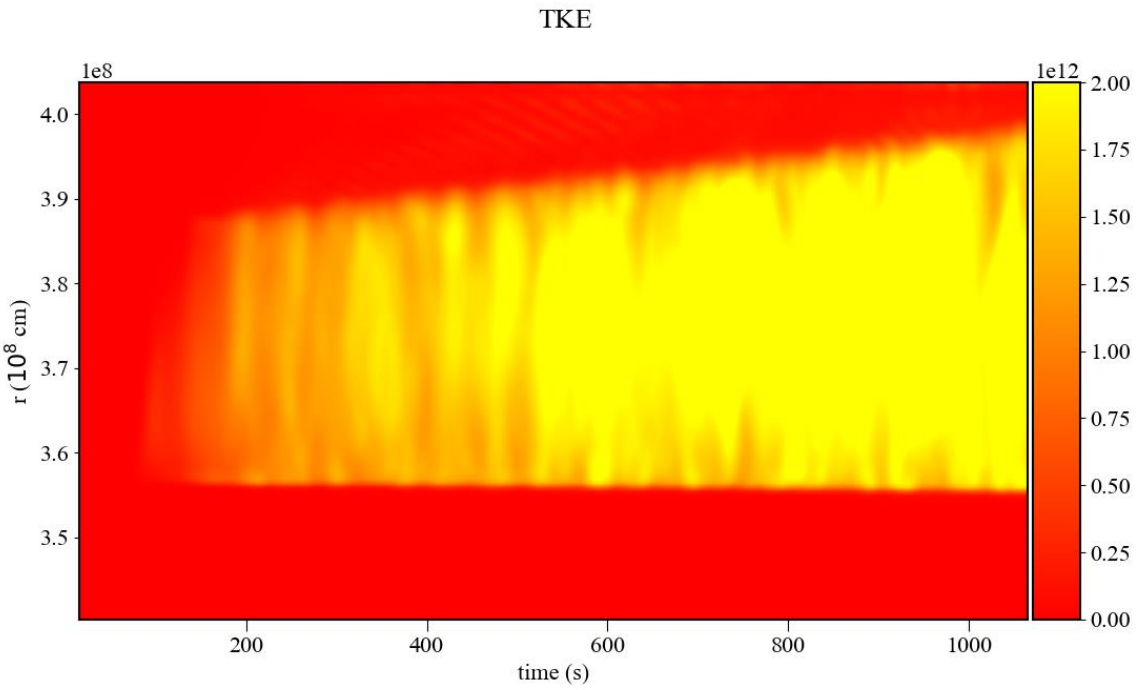
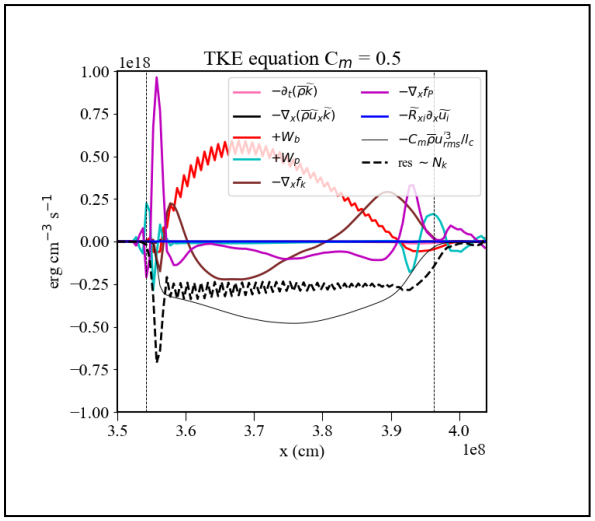
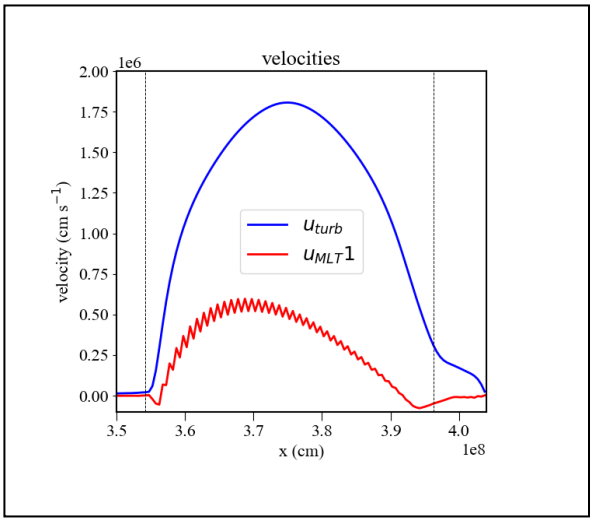
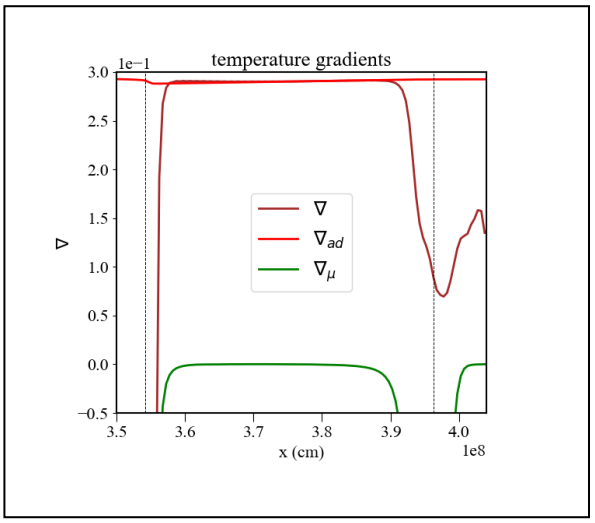
NESHELL (128x128x128) 25 element nuclear network, nuclear luminosity boost 10x

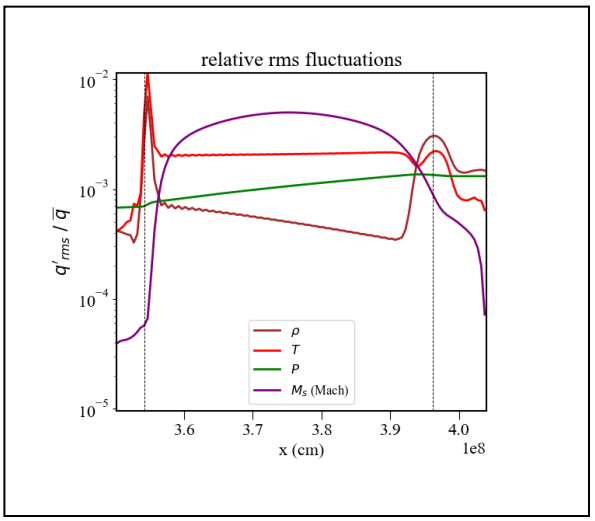
```
In [4]: run ransX.py
#-------------------------------------------------#
('Datafile with space-time averages: ', 'DATA_D/TSERIES/tseries_neshell_nucboost10x_tavg500.npy')
('Central time (in s): ', 770.0)
('Averaging windows (in s): ', 500.0)
('Time range (in s from-to): ', 500.0, 1080.0)
--------------
Resolution: 128 128 128
Radial size of computational domain (in cm): 3.40e+08 4.04e+08
Radial size of convection zone (in cm):  3.54e+08 3.96e+08
Extent of convection zone (in Hp): 0.428979
Averaging time window (in s): 500.000000
RMS velocities in convection zone (in cm/s):  2.00e+06
Convective turnover timescale (in s)  4.19e+01
P_turb o P_gas 2.08e-05
Mach number Max 4.98e-03
Mach number Mean 3.52e-03
Dissipation length scale (in cm): 1.06e+08
Total nuclear luminosity (in erg/s): 1.67e+42
Rate of TKE dissipation (in erg/s): 4.68e+40
Dissipation timescale for TKE (in s): 26.475498
Reynolds number: 367
```

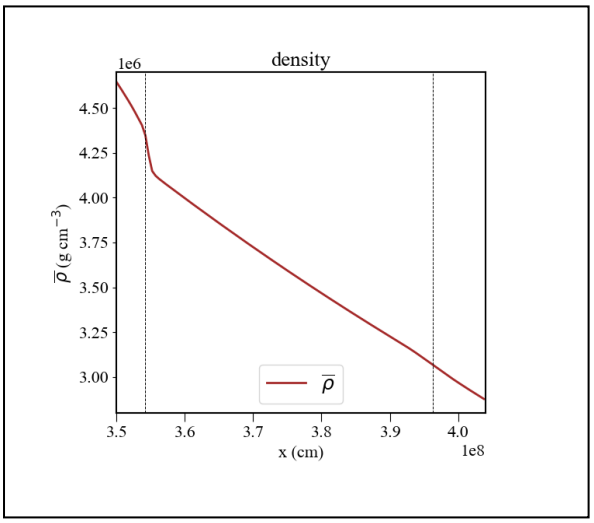


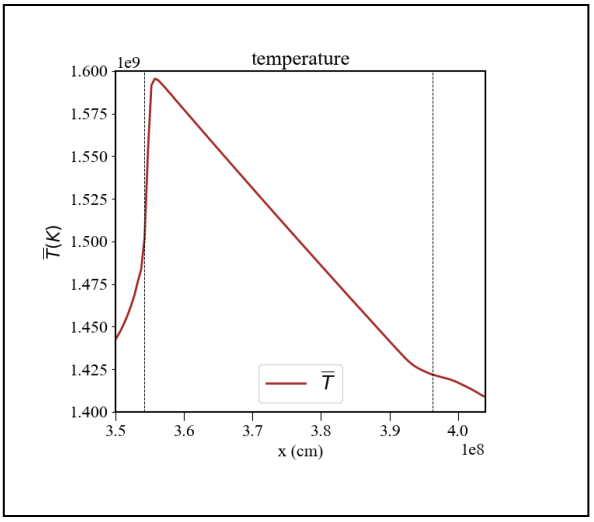


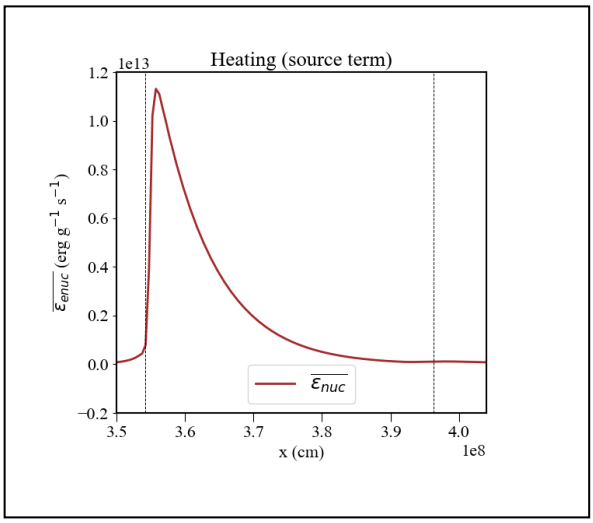


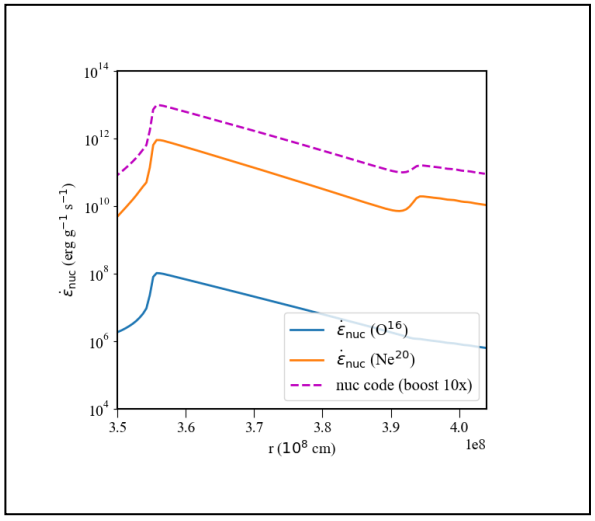

temperature gradients
1e−1
∇
∇ad
∇μ
x (cm)
1e8

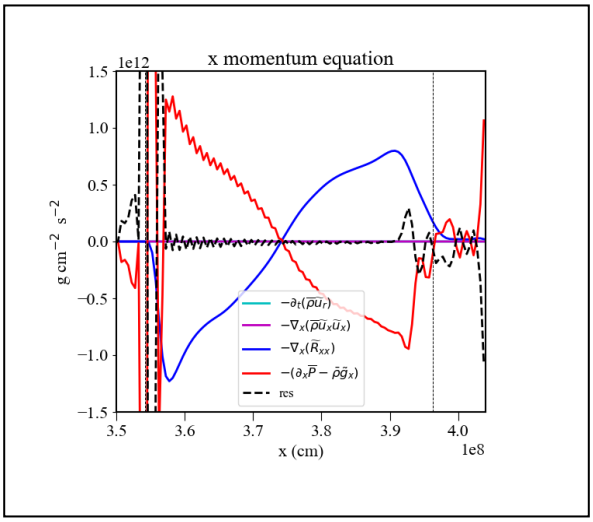

relative rms fluctuations
q′rms / q̄
ρ
T
P
Ms (Mach)
x (cm)
1e8

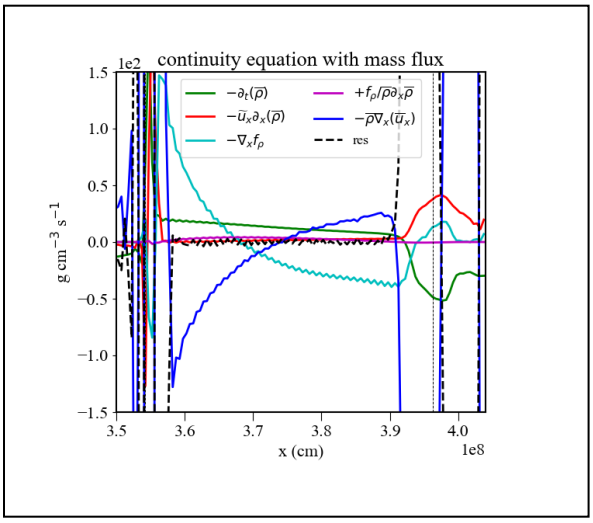

density
1e6
ρ̄ (g cm−3)
ρ̄
x (cm)
1e8

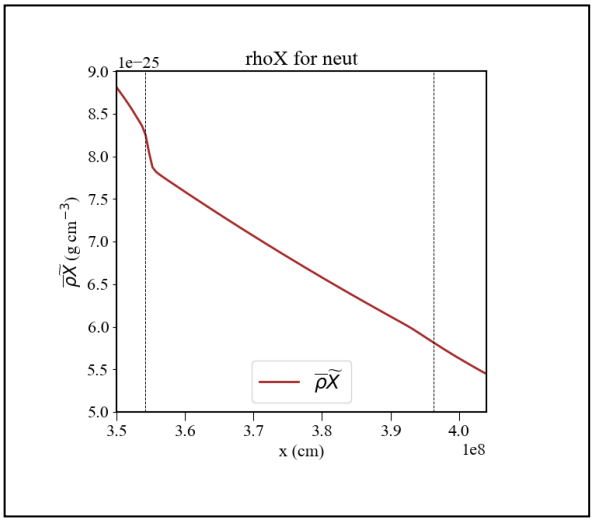

temperature
1e9
T̄(K)
T̄
x (cm)
1e8

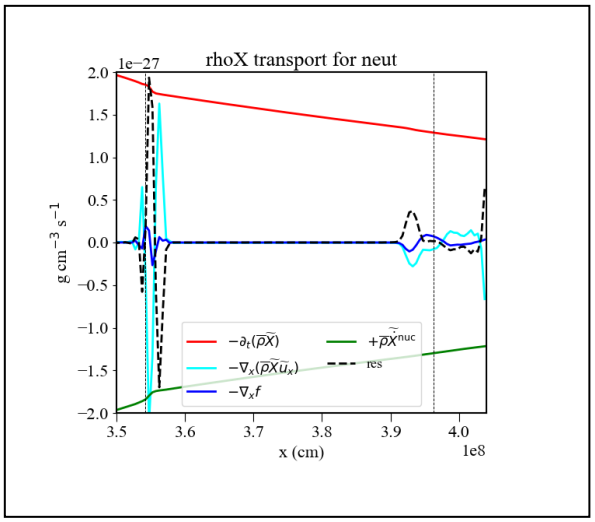

Heating (source term)
1e13
ε̄nuc (erg g−1 s−1)
ε̄nuc
x (cm)
1e8

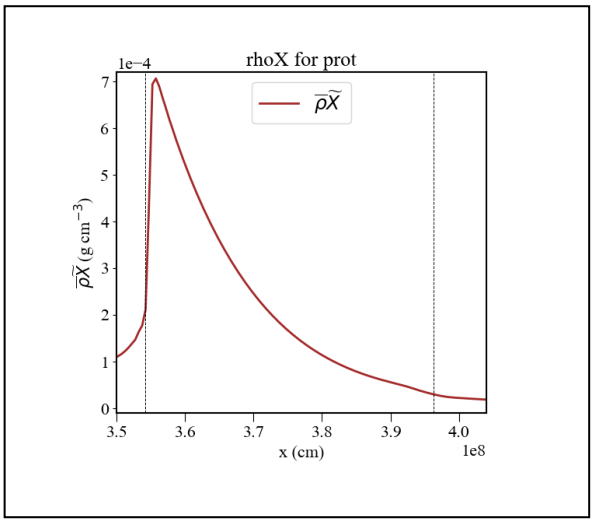

ε̇nuc (erg g−1 s−1)
ε̇nuc (O16)
ε̇nuc (Ne20)
nuc code (boost 10x)
r (10^8 cm)
1e8

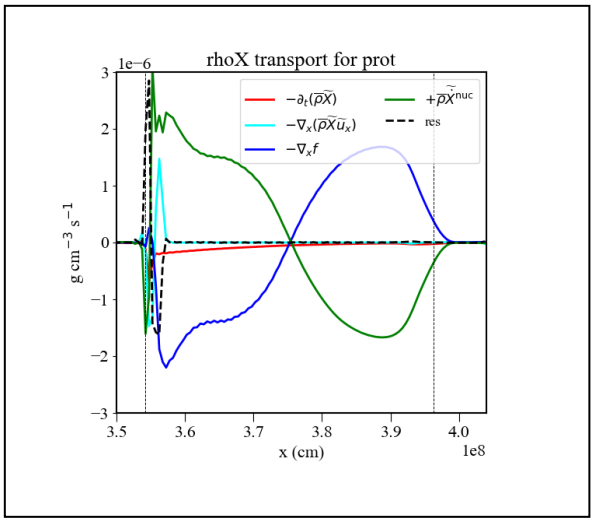

x momentum equation
1e12
g cm−2 s−2
−∂t(ρ̄ũr)
−∇x(ρ̄ũxũx)
−∇x(R̄xx)
−(∂xP̄ − ρ̄g̃x)
res
x (cm)
1e8

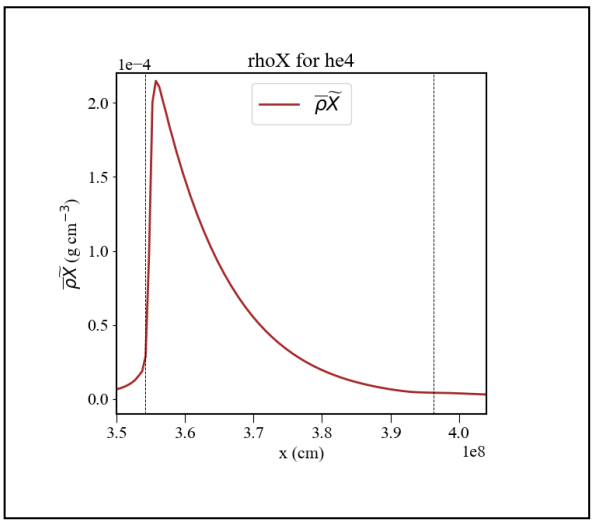

continuity equation with mass flux
1e2
g cm−3 s−1
−∂t(ρ̄)
−ũx∂x(ρ̄)
−∇xfρ
+fρ/ρ̄∂xρ̄
−ρ̄∇x(ũx)
res
x (cm)
1e8

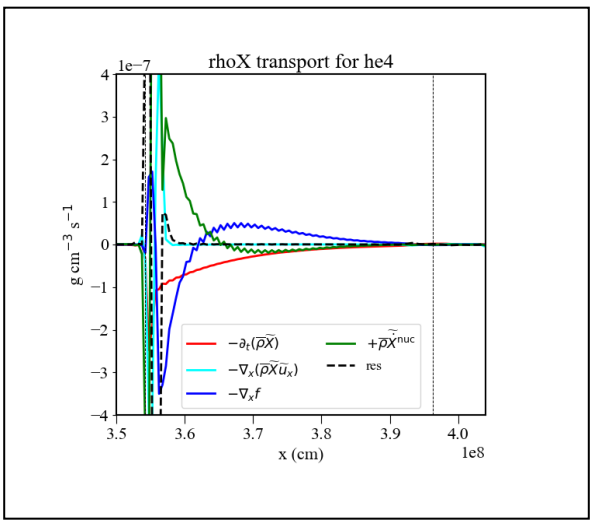

rhoX for neut
1e−25
$\overline{\rho X}$ (g cm^{-3})
x (cm)
1e8
$\overline{\rho X}$

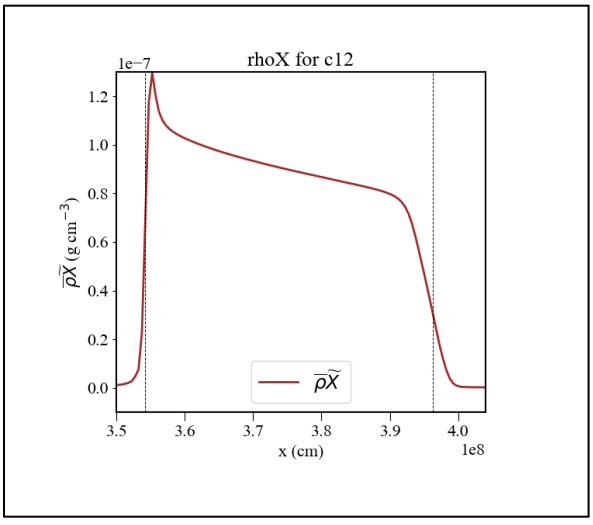

rhoX transport for neut
1e−27
g cm^{-3} s^{-1}
x (cm)
1e8
$-\partial_t(\overline{\rho X})$
$-\nabla_x(\overline{\rho X}\tilde{u}_x)$
$-\nabla_x f$
$+\overline{\rho X}^{\rm nuc}$
res

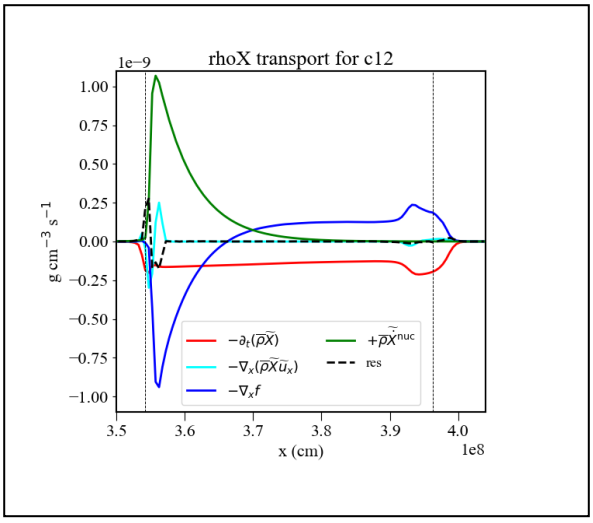

rhoX for prot
1e−4
$\overline{\rho X}$ (g cm^{-3})
x (cm)
1e8
$\overline{\rho X}$

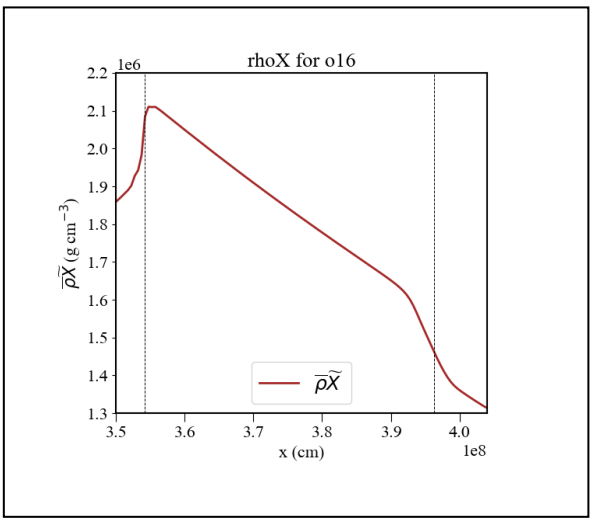

rhoX transport for prot
1e−6
g cm^{-3} s^{-1}
x (cm)
1e8
$-\partial_t(\overline{\rho X})$
$-\nabla_x(\overline{\rho X}\tilde{u}_x)$
$-\nabla_x f$
$+\overline{\rho X}^{\rm nuc}$
res

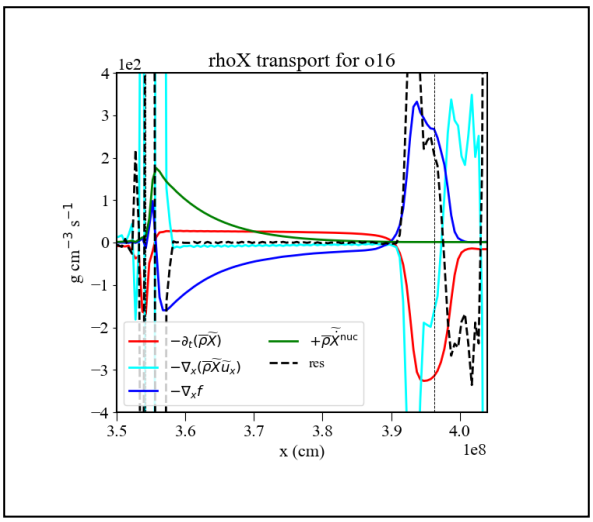

rhoX for he4
1e−4
$\overline{\rho X}$ (g cm^{-3})
x (cm)
1e8
$\overline{\rho X}$

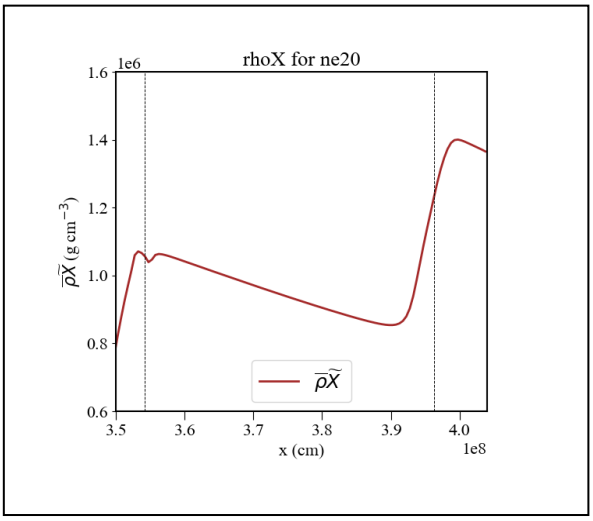

rhoX transport for he4
1e−7
g cm^{-3} s^{-1}
x (cm)
1e8
$-\partial_t(\overline{\rho X})$
$-\nabla_x(\overline{\rho X}\tilde{u}_x)$
$-\nabla_x f$
$+\overline{\rho X}^{\rm nuc}$
res

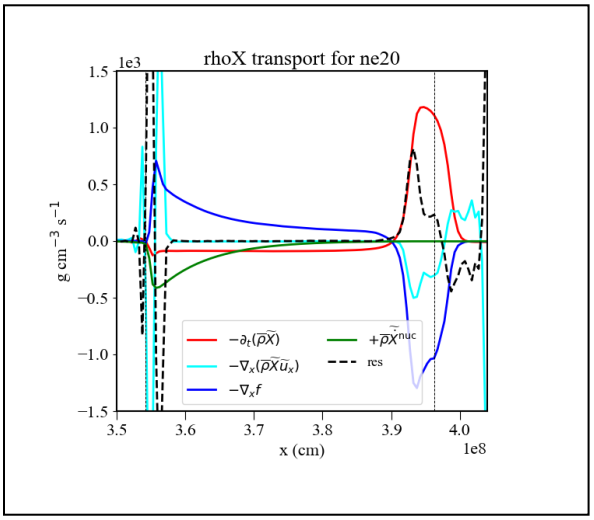

rhoX for c12
1e−7
$\overline{\rho X}$ (g cm^{-3})
x (cm)
1e8
$\overline{\rho X}$

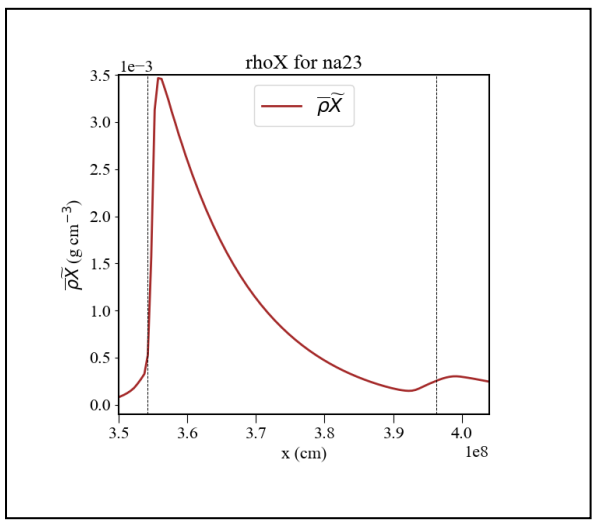

rhoX transport for c12
1e−9
g cm^{-3} s^{-1}
x (cm)
1e8
$-\partial_t(\overline{\rho X})$
$-\nabla_x(\overline{\rho X}\tilde{u}_x)$
$-\nabla_x f$
$+\overline{\rho X}^{\rm nuc}$
res

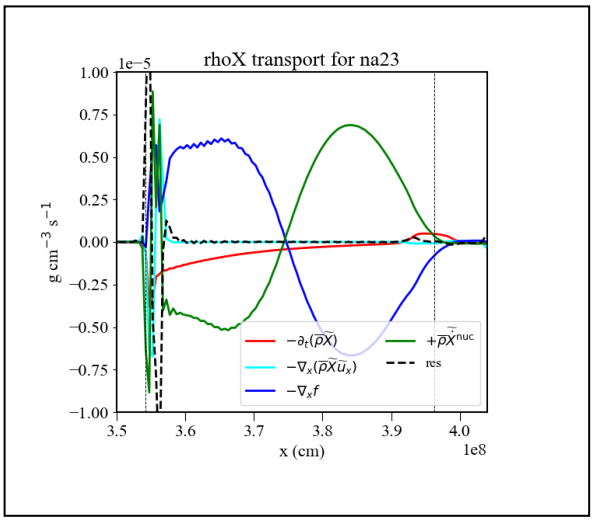

rhoX for o16
1e6
$\overline{\rho X}$ (g cm^{-3})
$\overline{\rho X}$
x (cm)
1e8

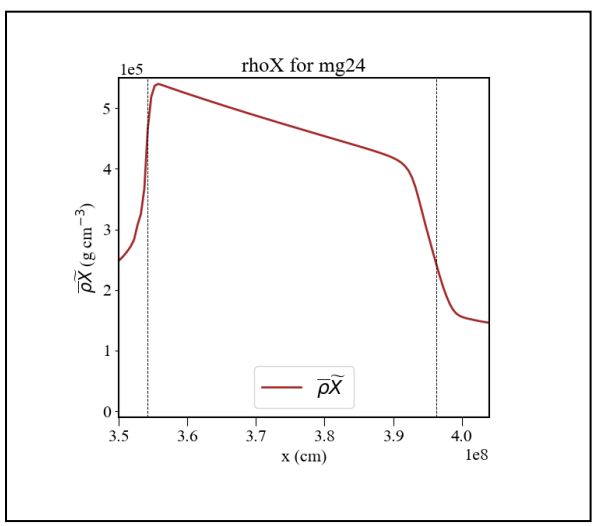

rhoX transport for o16
1e2
g cm^{-3} s^{-1}
$-\partial_t(\overline{\rho X})$
$-\nabla_x(\overline{\rho X}\tilde{u}_x)$
$-\nabla_x f$
$+\overline{\rho X}^{\mathrm{nuc}}$
res
x (cm)
1e8

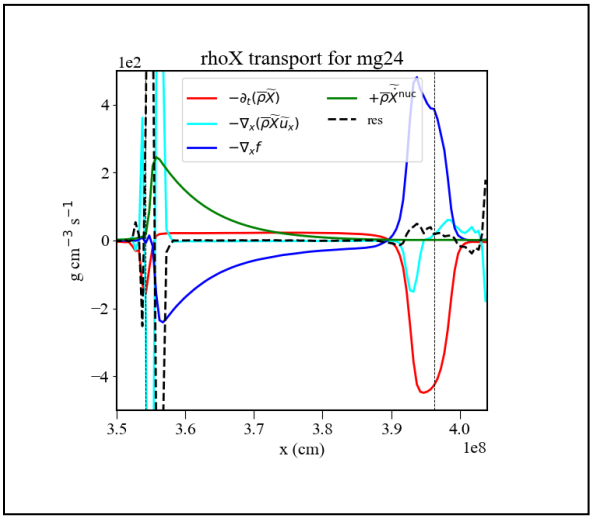

rhoX for ne20
1e6
$\overline{\rho X}$ (g cm^{-3})
$\overline{\rho X}$
x (cm)
1e8

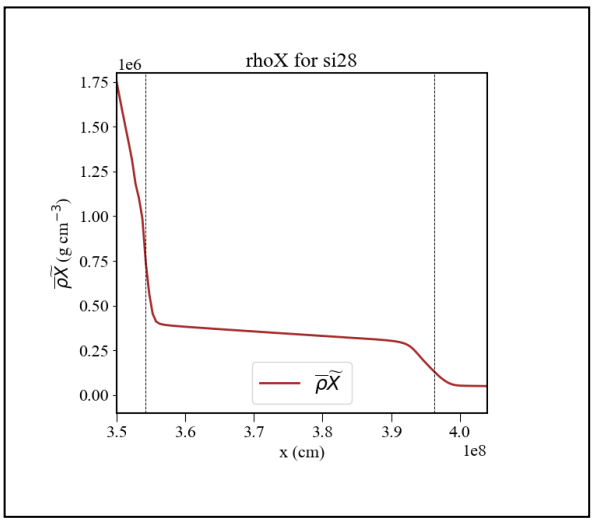

rhoX transport for ne20
1e3
g cm^{-3} s^{-1}
$-\partial_t(\overline{\rho X})$
$-\nabla_x(\overline{\rho X}\tilde{u}_x)$
$-\nabla_x f$
$+\overline{\rho X}^{\mathrm{nuc}}$
res
x (cm)
1e8

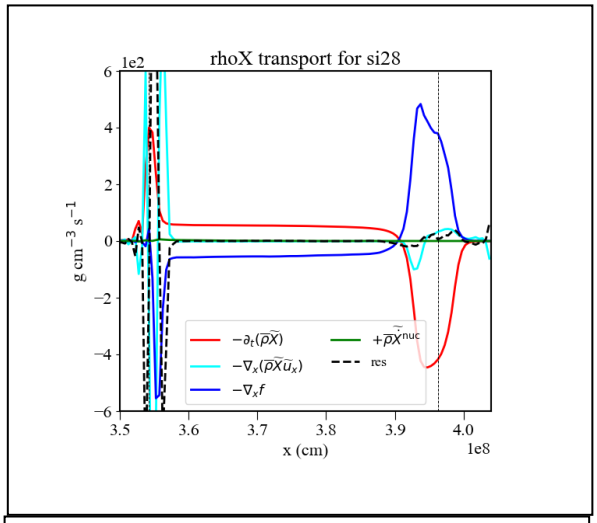

rhoX for na23
1e−3
$\overline{\rho X}$ (g cm^{-3})
$\overline{\rho X}$
x (cm)
1e8

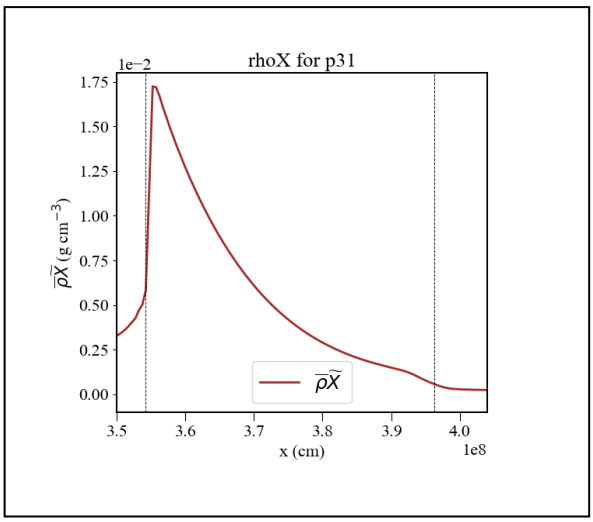

rhoX transport for na23
1e−5
g cm^{-3} s^{-1}
$-\partial_t(\overline{\rho X})$
$-\nabla_x(\overline{\rho X}\tilde{u}_x)$
$-\nabla_x f$
$+\overline{\rho X}^{\mathrm{nuc}}$
res
x (cm)
1e8

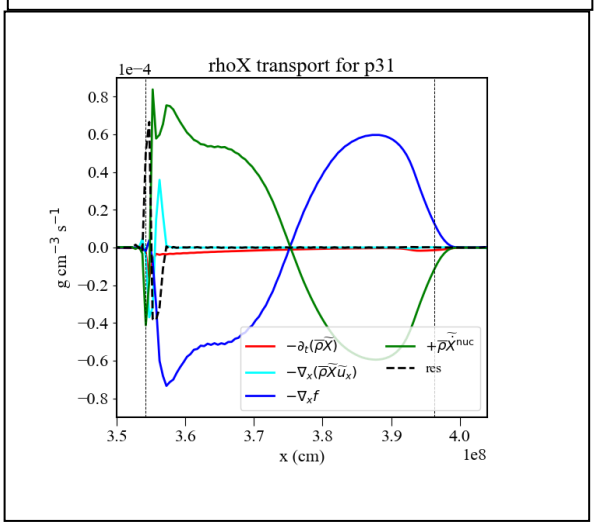

rhoX for mg24
1e5
$\overline{\rho X}$ (g cm^{-3})
$\overline{\rho X}$
x (cm)
1e8

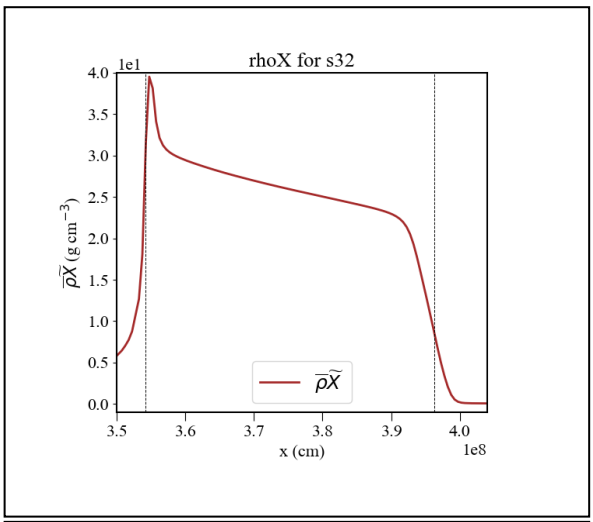

rhoX transport for mg24
1e2
g cm^{-3} s^{-1}
$-\partial_t(\overline{\rho X})$
$-\nabla_x(\overline{\rho X}\tilde{u}_x)$
$-\nabla_x f$
$+\overline{\rho X}^{\mathrm{nuc}}$
res
x (cm)
1e8

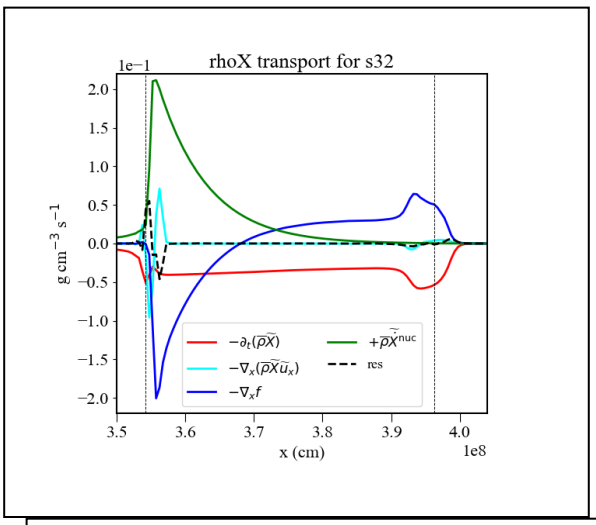

rhoX for si28
1e6
$\overline{\rho X}$ (g cm^{-3})
$\overline{\rho X}$
x (cm)
1e8

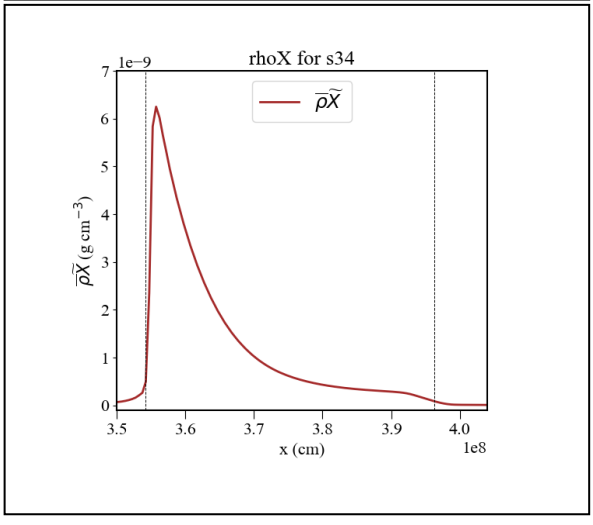

rhoX transport for si28
1e2
g cm^{-3} s^{-1}
$-\partial_t(\overline{\rho X})$
$-\nabla_x(\overline{\rho X}\tilde{u}_x)$
$-\nabla_x f$
$+\overline{\rho X}^{\rm nuc}$
res
x (cm)
1e8

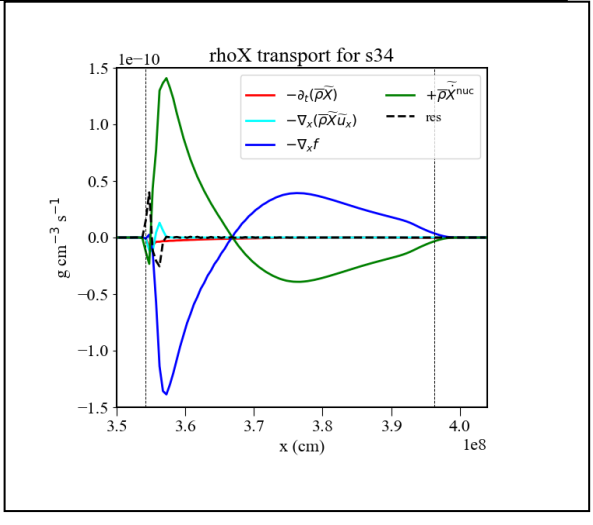

rhoX for p31
1e−2
$\overline{\rho X}$ (g cm^{-3})
$\overline{\rho X}$
x (cm)
1e8

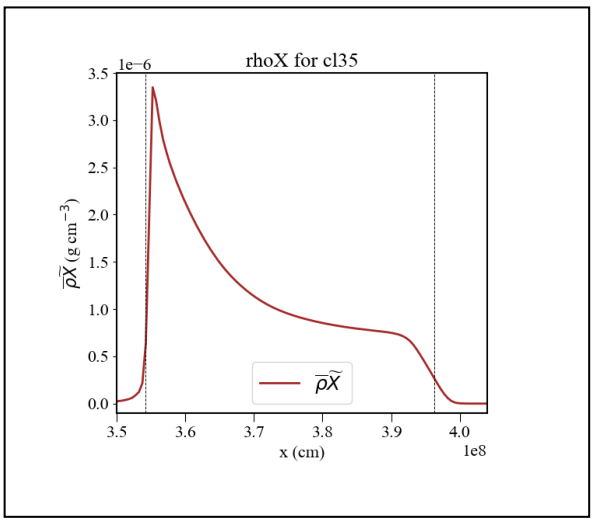

rhoX transport for p31
1e−4
g cm^{-3} s^{-1}
$-\partial_t(\overline{\rho X})$
$-\nabla_x(\overline{\rho X}\tilde{u}_x)$
$-\nabla_x f$
$+\overline{\rho X}^{\rm nuc}$
res
x (cm)
1e8

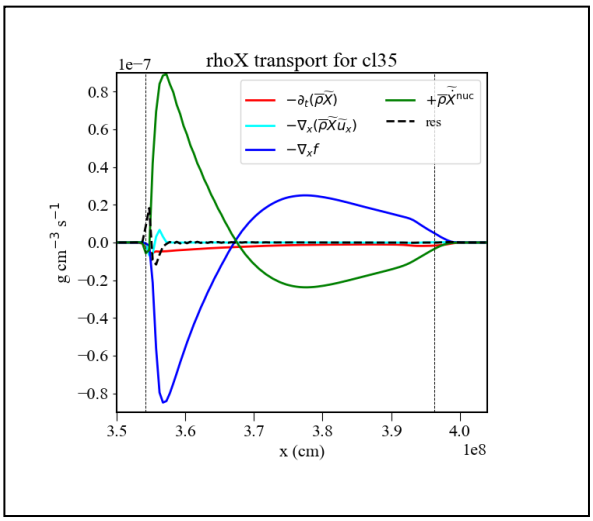

rhoX for s32
1e1
$\overline{\rho X}$ (g cm^{-3})
$\overline{\rho X}$
x (cm)
1e8

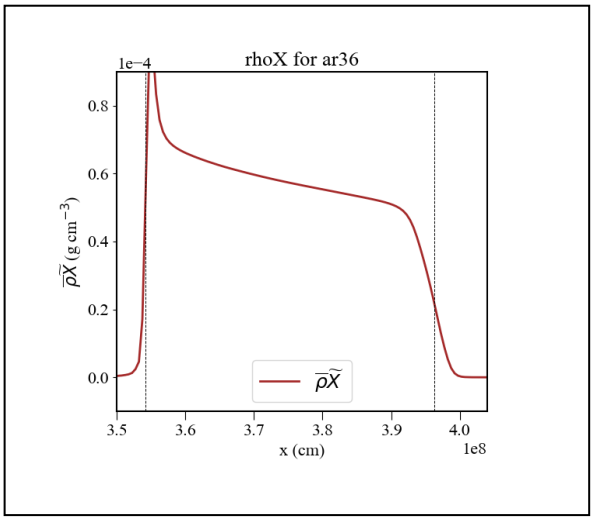

rhoX transport for s32
1e−1
g cm^{-3} s^{-1}
$-\partial_t(\overline{\rho X})$
$-\nabla_x(\overline{\rho X}\tilde{u}_x)$
$-\nabla_x f$
$+\overline{\rho X}^{\rm nuc}$
res
x (cm)
1e8

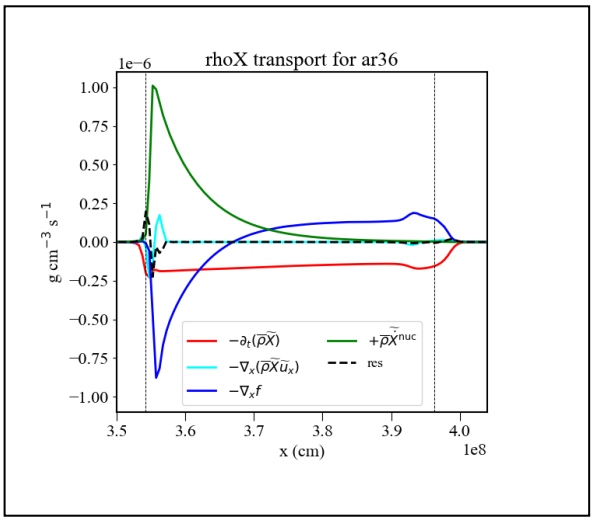

rhoX for s34
1e−9
$\overline{\rho X}$ (g cm^{-3})
$\overline{\rho X}$
x (cm)
1e8

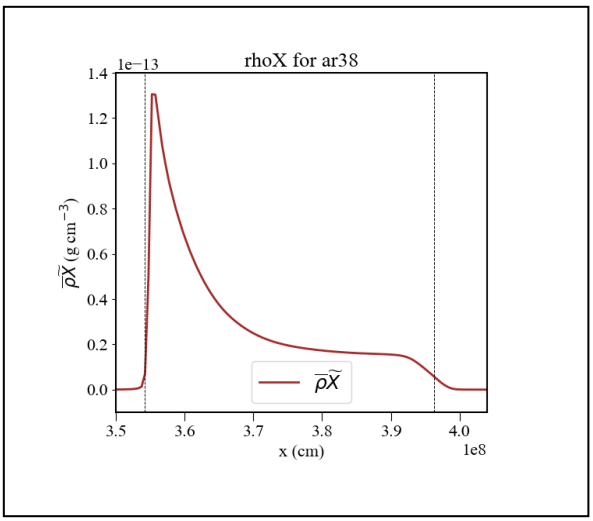

rhoX transport for s34
1e−10
g cm^{-3} s^{-1}
$-\partial_t(\overline{\rho X})$
$-\nabla_x(\overline{\rho X}\tilde{u}_x)$
$-\nabla_x f$
$+\overline{\rho X}^{\rm nuc}$
res
x (cm)
1e8

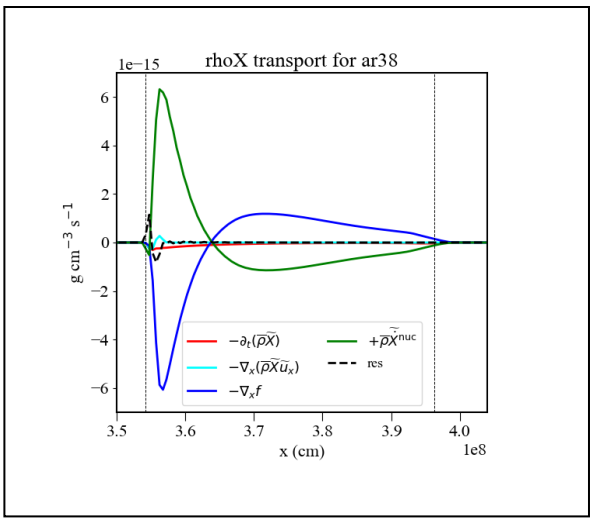

rhoX for cl35
1e−6
$\overline{\rho X}$ (g cm^{-3})
$\overline{\rho X}$
x (cm)
1e8

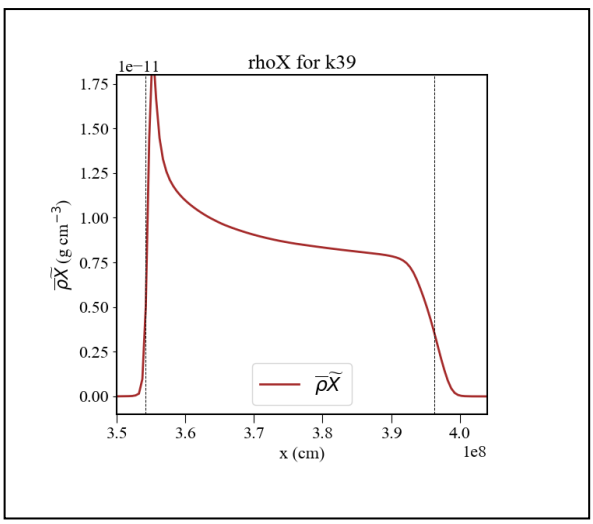

rhoX transport for cl35
1e−7
g cm^{-3} s^{-1}
$-\partial_t(\overline{\rho X})$
$-\nabla_x(\overline{\rho X}\widetilde{u}_x)$
$-\nabla_x f$
$+\overline{\rho X}^{\mathrm{nuc}}$
res
x (cm)
1e8

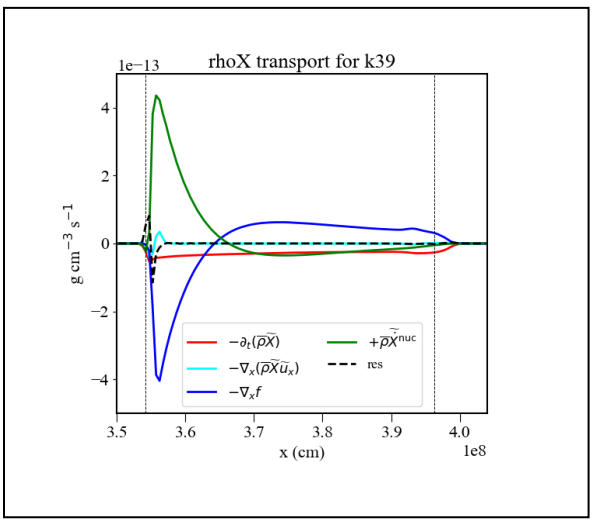

rhoX for ar36
1e−4
$\overline{\rho X}$ (g cm^{-3})
$\overline{\rho X}$
x (cm)
1e8

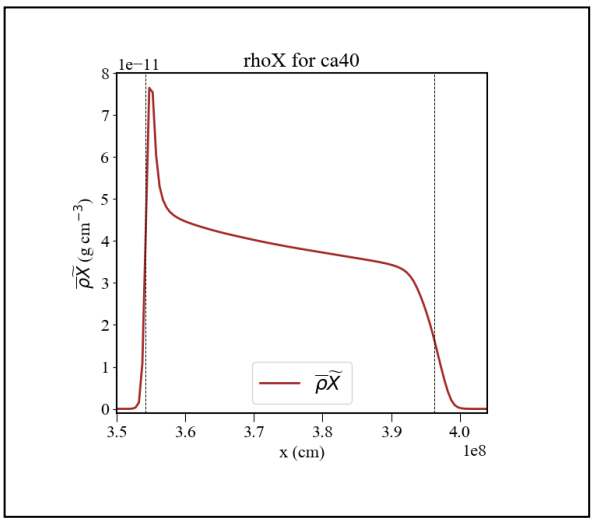

rhoX transport for ar36
1e−6
g cm^{-3} s^{-1}
$-\partial_t(\overline{\rho X})$
$-\nabla_x(\overline{\rho X}\widetilde{u}_x)$
$-\nabla_x f$
$+\overline{\rho X}^{\mathrm{nuc}}$
res
x (cm)
1e8

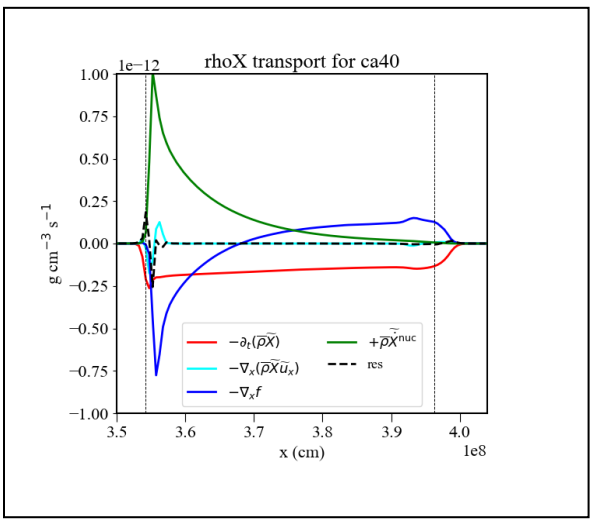

rhoX for ar38
1e−13
$\overline{\rho X}$ (g cm^{-3})
$\overline{\rho X}$
x (cm)
1e8

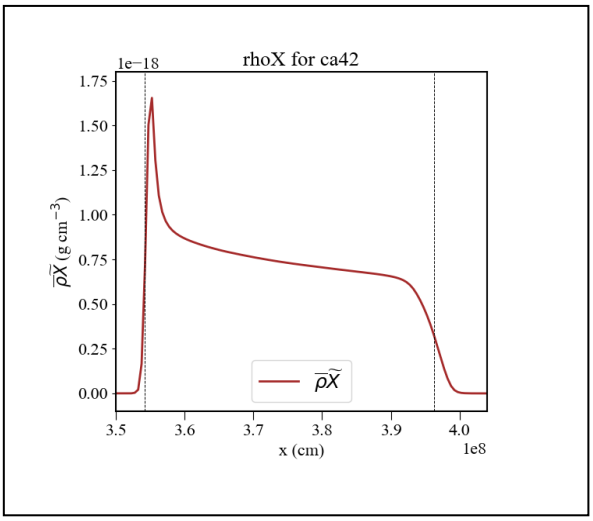

rhoX transport for ar38
1e−15
g cm^{-3} s^{-1}
$-\partial_t(\overline{\rho X})$
$-\nabla_x(\overline{\rho X}\widetilde{u}_x)$
$-\nabla_x f$
$+\overline{\rho X}^{\mathrm{nuc}}$
res
x (cm)
1e8

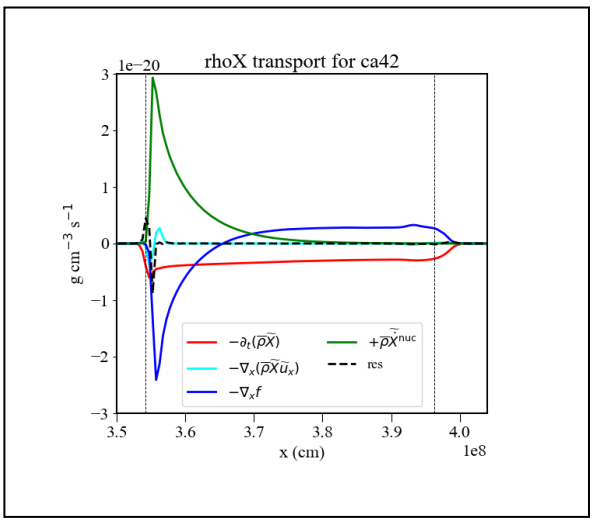

rhoX for k39
1e−11
$\overline{\rho X}$ (g cm^{-3})
$\overline{\rho X}$
x (cm)
1e8

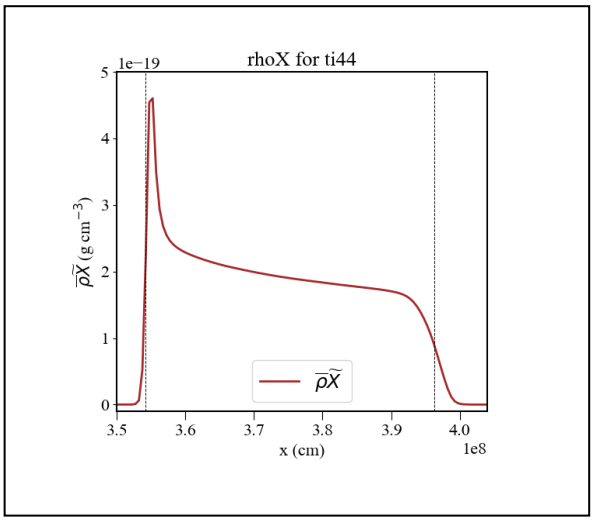

rhoX transport for k39
1e−13
g cm^{-3} s^{-1}
$-\partial_t(\overline{\rho X})$
$-\nabla_x(\overline{\rho X}\widetilde{u}_x)$
$-\nabla_x f$
$+\overline{\rho X}^{\mathrm{nuc}}$
res
x (cm)
1e8

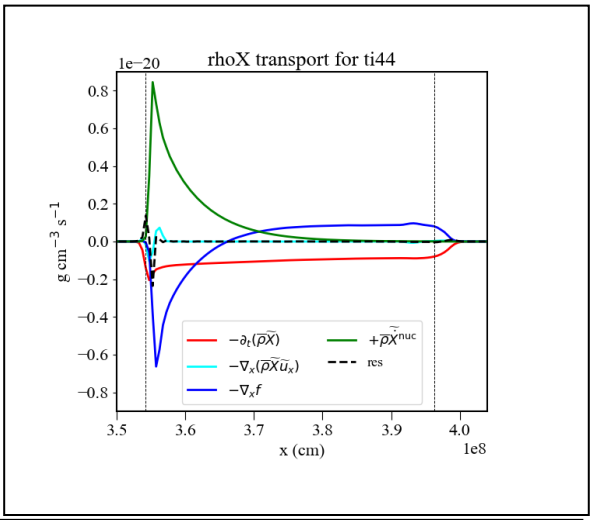

rhoX for ca40
1e−11
$\overline{\rho X}$ (g cm^{-3})
$\overline{\rho X}$
x (cm)
1e8

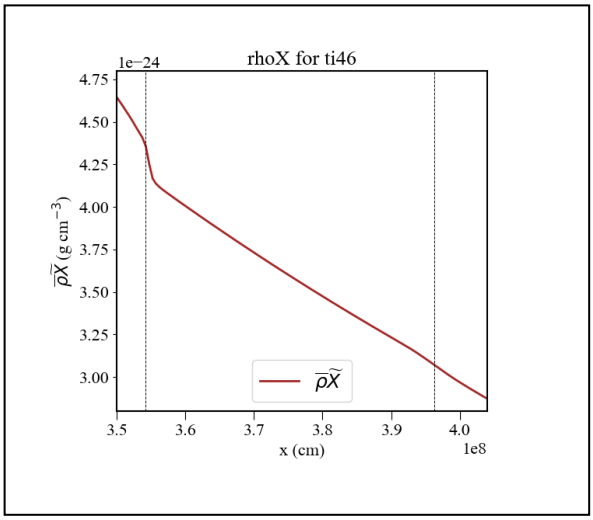

rhoX transport for ca40
1e−12
g cm^{-3} s^{-1}
$-\partial_t(\overline{\rho X})$
$-\nabla_x(\overline{\rho X}\widetilde{u}_x)$
$-\nabla_x f$
$+\overline{\rho X}^{\text{nuc}}$
res
x (cm)
1e8

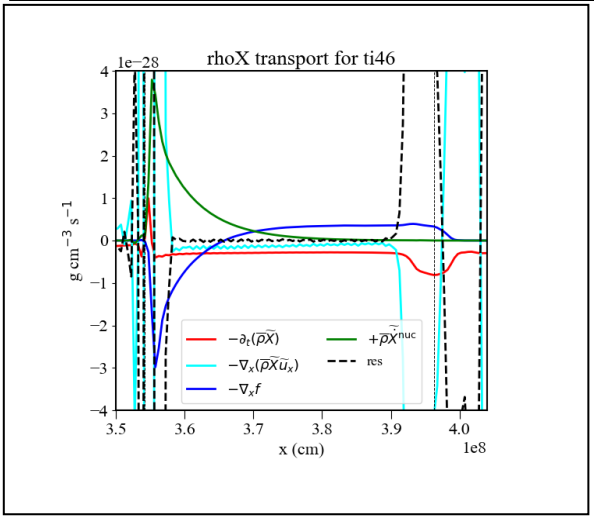

rhoX for ca42
1e−18
$\overline{\rho X}$ (g cm^{-3})
$\overline{\rho X}$
x (cm)
1e8

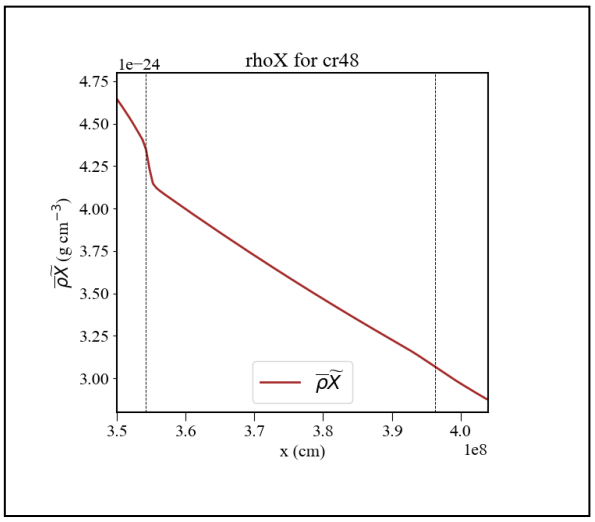

rhoX transport for ca42
1e−20
g cm^{-3} s^{-1}
$-\partial_t(\overline{\rho X})$
$-\nabla_x(\overline{\rho X}\widetilde{u}_x)$
$-\nabla_x f$
$+\overline{\rho X}^{\text{nuc}}$
res
x (cm)
1e8

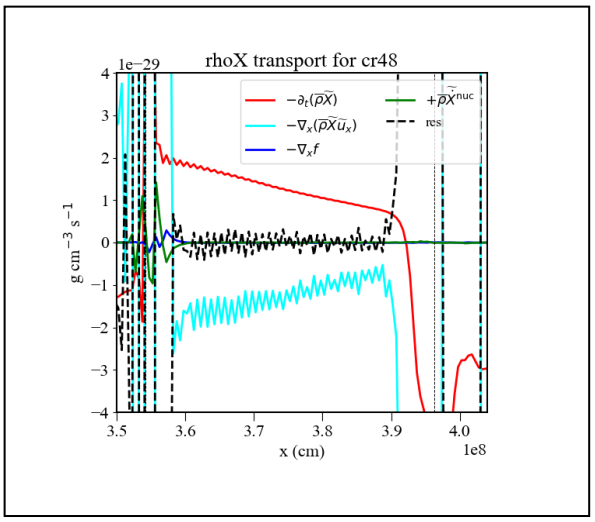

rhoX for ti44
1e−19
$\overline{\rho X}$ (g cm^{-3})
$\overline{\rho X}$
x (cm)
1e8

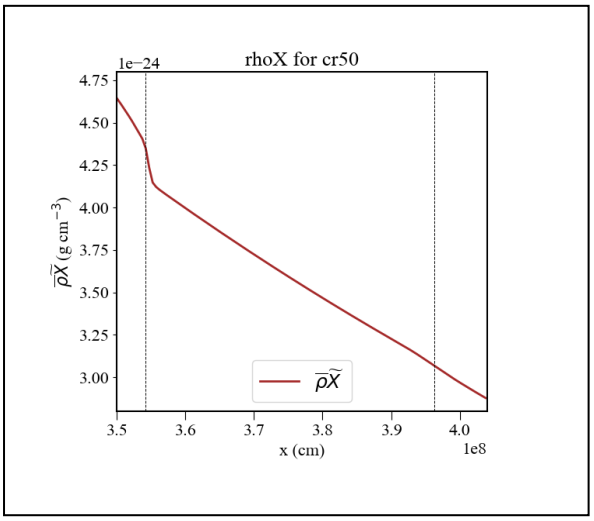

rhoX transport for ti44
1e−20
g cm^{-3} s^{-1}
$-\partial_t(\overline{\rho X})$
$-\nabla_x(\overline{\rho X}\widetilde{u}_x)$
$-\nabla_x f$
$+\overline{\rho X}^{\text{nuc}}$
res
x (cm)
1e8

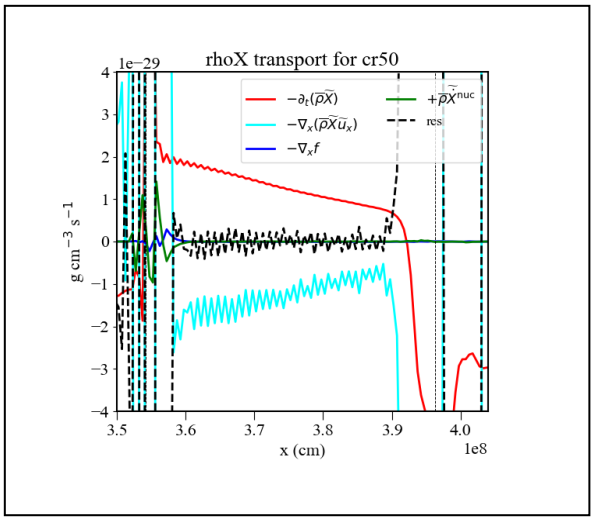

rhoX for ti46
1e−24
$\overline{\rho X}$ (g cm^{-3})
$\overline{\rho X}$
x (cm)
1e8

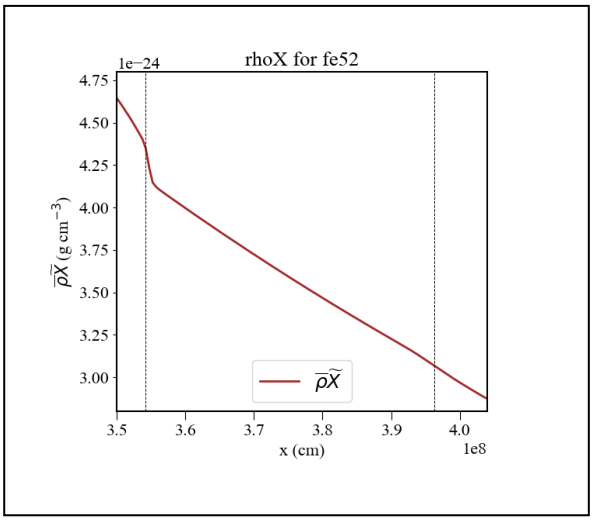

rhoX transport for ti46
1e−28
g cm^{-3} s^{-1}
$-\partial_t(\overline{\rho X})$
$-\nabla_x(\overline{\rho X}\widetilde{u}_x)$
$-\nabla_x f$
$+\overline{\rho X}^{\text{nuc}}$
res
x (cm)
1e8

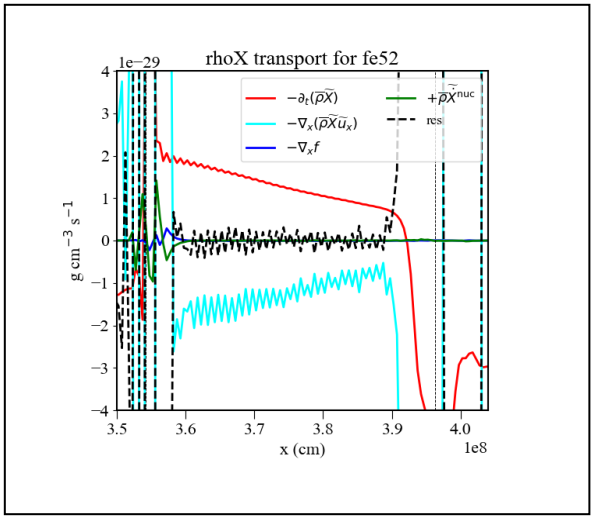

rhoX for cr48
1e−24
$\overline{\rho}\widetilde{X}$ (g cm^{-3})
x (cm)
1e8
$\overline{\rho}\widetilde{X}$

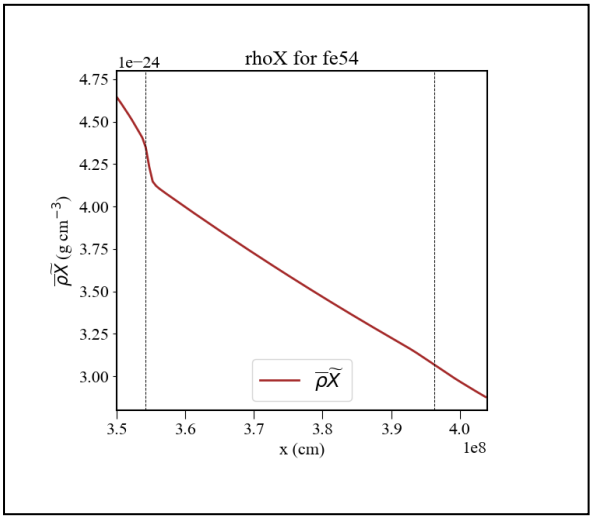

rhoX transport for cr48
1e−29
g cm^{-3} s^{-1}
x (cm)
1e8
$-\partial_t(\overline{\rho}\widetilde{X})$
$-\nabla_x(\overline{\rho}\widetilde{X}\widetilde{u}_x)$
$-\nabla_x f$
$+\overline{\rho}\widetilde{X}^{\mathrm{nuc}}$
res

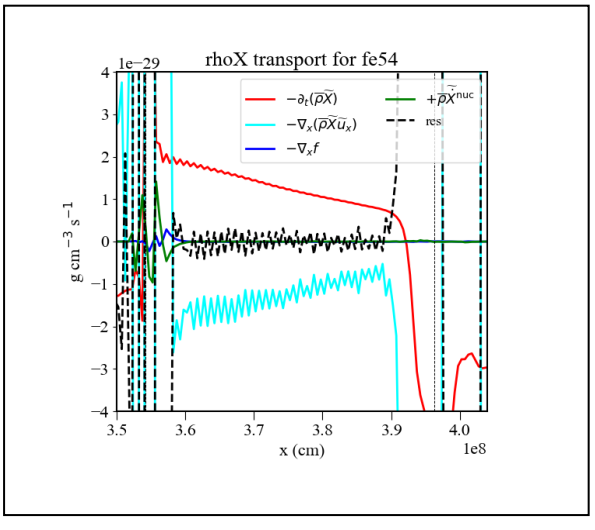

rhoX for cr50
1e−24
$\overline{\rho}\widetilde{X}$ (g cm^{-3})
x (cm)
1e8
$\overline{\rho}\widetilde{X}$

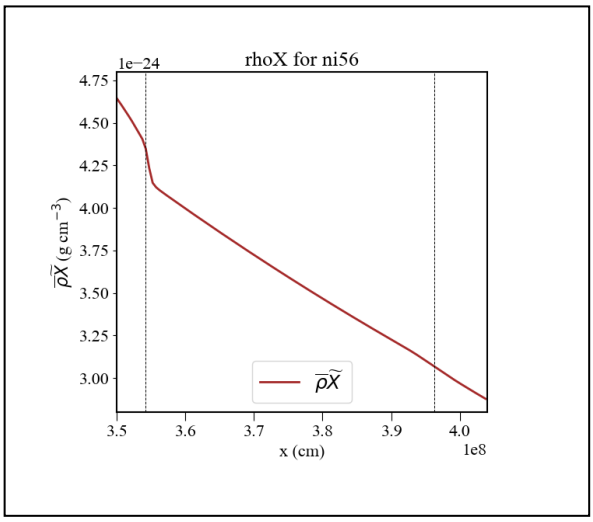

rhoX transport for cr50
1e−29
g cm^{-3} s^{-1}
x (cm)
1e8
$-\partial_t(\overline{\rho}\widetilde{X})$
$-\nabla_x(\overline{\rho}\widetilde{X}\widetilde{u}_x)$
$-\nabla_x f$
$+\overline{\rho}\widetilde{X}^{\mathrm{nuc}}$
res

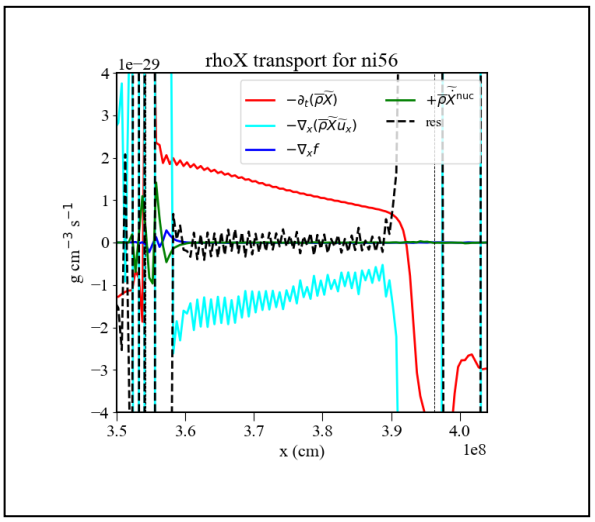

rhoX for fe52
1e−24
$\overline{\rho}\widetilde{X}$ (g cm^{-3})
x (cm)
1e8
$\overline{\rho}\widetilde{X}$


rhoX transport for fe52
1e−29
g cm^{-3} s^{-1}
x (cm)
1e8
$-\partial_t(\overline{\rho}\widetilde{X})$
$-\nabla_x(\overline{\rho}\widetilde{X}\widetilde{u}_x)$
$-\nabla_x f$
$+\overline{\rho}\widetilde{X}^{\mathrm{nuc}}$
res


rhoX for fe54
1e−24
$\overline{\rho}\widetilde{X}$ (g cm^{-3})
x (cm)
1e8
$\overline{\rho}\widetilde{X}$


rhoX transport for fe54
1e−29
g cm^{-3} s^{-1}
x (cm)
1e8
$-\partial_t(\overline{\rho}\widetilde{X})$
$-\nabla_x(\overline{\rho}\widetilde{X}\widetilde{u}_x)$
$-\nabla_x f$
$+\overline{\rho}\widetilde{X}^{\mathrm{nuc}}$
res





NESHELL 128x128x128

: original rates

```
0      ne20   he4   o16                              cf88nv    -4.73400E+00
 0.637915E+02-0.549729E+02-0.343457E+02-0.251939E+02
 0.479855E+01-0.146444E+01 0.784333E+01
0      ne20   he4   o16                              cf88rv    -4.73400E+00
 0.109310E+03-0.727584E+02 0.293664E+03-0.384974E+03
 0.202380E+02-0.100379E+01 0.201193E+03
```

```
0      he4  ne20  mg24                             cf88n     9.31200E+00
 0.321588E+02-0.151494E-01-0.446410E+02-0.833867E+01
 0.241631E+01-0.778056E+00 0.193576E+01
0      he4  ne20  mg24                             cf88r     9.31200E+00
-0.291641E+03-0.120966E+02-0.633725E+02 0.394643E+03
-0.362432E+02 0.264060E+01-0.121219E+03
```

- boost 10x

: new rates (added ln10 to first rate coefficient)

```
0      ne20   he4   o16                              cf88nv    -4.73400E+00
 0.660941E+02-0.549729E+02-0.343457E+02-0.251939E+02
 0.479855E+01-0.146444E+01 0.784333E+01
0      ne20   he4   o16                              cf88rv    -4.73400E+00
 0.111613E+03-0.727584E+02 0.293664E+03-0.384974E+03
 0.202380E+02-0.100379E+01 0.201193E+03
```

```
0      he4  ne20  mg24                             cf88n     9.31200E+00
 0.344614E+02-0.151494E-01-0.446410E+02-0.833867E+01
 0.241631E+01-0.778056E+00 0.193576E+01
0      he4  ne20  mg24                             cf88r     9.31200E+00
-0.289338E+03-0.120966E+02-0.633725E+02 0.394643E+03
-0.362432E+02 0.264060E+01-0.121219E+03
```