The SRG transformation of the Hamiltonian is defined by:

$$H(s) = U(s) H U^\dagger(s)$$

with the *unitary* operator $U(s)$, the Hamiltonian $H(s) = T_{rel} + V_{\mathrm{NN}}(s)$ and the resolution scale s .

Show that the flow equation is given by:

$$\frac{dH(s)}{ds} = [\eta(s), H(s)]$$

with the *anti-unitary* g*enerator*

$$\eta(s) = \frac{dU(s)}{ds} U^\dagger(s) = -\eta^\dagger(s)$$

The generator specifies the RG transformation and can be chosen suitably, such that the desired decoupling is achieved. The by far most common choice is:

$$\eta(s) = [T_{rel}, H(s)]$$

Where the kinetic energy operator is diagonal and hence hermitian. Show that the resulting generator is *anti-unitary*.

$$\frac{dH(s)}{ds} = [[T_{rel}, H(s)], H(s)]$$

1 Familiarize yourself with the first version of the code. This code allows you to read in matrix elements $V_{\mathrm{NN}}(s=0)$ and visualise them. Take a look at different coupled and uncoupled channels. In addition, a routine for computing the deuteron binding energy and phase shifts is included. Reproduce the experimental observables using the provided interaction matrix elements.

2 Implement a routine that allows to solve the SRG flow equations. For this you can use the NumPy routine **odeint**. You can use the upper limit $s \sim 0.1\ \mathrm{fm}^4$ as an upper limit for the resolution scale.

3 Visualize the SRG-evolved interaction matrix elements using coloured contour plots and verify that the off-diagonal matrix elements get successively suppressed with increasing flow parameter. Verify that the deuteron binding energy remains invariant during the SRG evolution within numerical accuracy.

4 Modify the routine for the deuteron binding energy such that you can control the momentum range of the matrices. Show that you can reduce the dimensionality of the eigenvalue problem by cutting away high-momentum modes, without changing the binding energy for sufficiently large flow parameter values s .

5 Verify that also the phase shifts remain invariant under SRG transformations.

Compare the results and run times of the code for the two interactions AV18 und EM500.