First tests

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To start the resoluiton of the problem we compute with the Crank Nicolson method the time evolution for $g = 0$ and $V_{ext} = 0$ then the equation reads as:

$$i\frac{\partial \Psi(\tilde{z},\tilde{t})}{\partial \tilde{t}} = -\frac{\partial^2 \Psi(\tilde{z},\tilde{t})}{\partial \tilde{z}^2} \tag{1}$$

1 Gaussian

To start testing the method we compute the time evolution for a gaussian function centered at zero and with $\sigma = 1$. We expect it to evolve as it is not an eigenfunction of $H = -\frac{\partial^2}{\partial \tilde{z}^2}$.

We compute the method for a spacing of $\Delta\tilde{z} = 0.01$ with $\tilde{z} \in [-3, 3]$ and a time interval $\delta\tilde{t} = 0.001$.

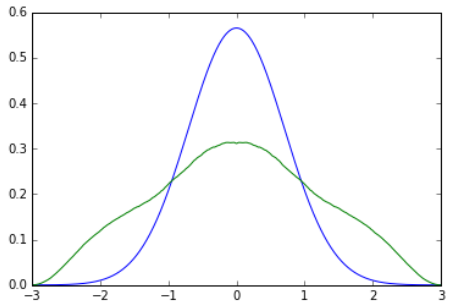

Figure 1: $|\Psi|^2$ *at time* $\tilde{t} = 0$ *in blue and at time* $\tilde{t} = 5$ *in green*

The maximum diference between the norm at $\tilde{t} = 0$ and the norm of the evolving function was: $1.16233793701x10^{-7}$

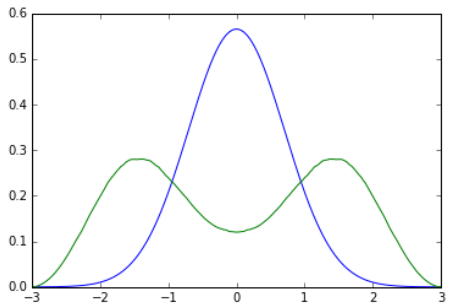

Figure 2: $|\Psi|^2$ *at time* $\tilde{t} = 0$ *in blue and at time* $\tilde{t} = 10$ *in green*

The maximum diference between the norm at $\tilde{t} = 0$ and the norm of the evolving function was: $1.16241938852x10^{-7}$

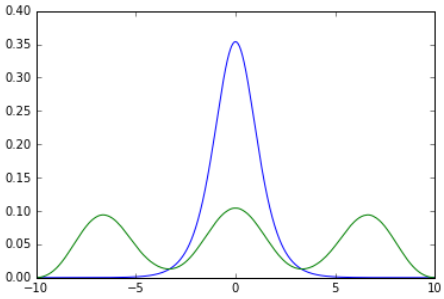

Figure 3: $|\Psi|^2$ *at time* $\tilde{t} = 0$ *in blue and at time* $\tilde{t} = 10$ *in green*

2 Bright soliton

2.1 null velocity

We compute the method for a spacing of $\Delta\tilde{z} = 0.01$ with $\tilde{z} \in [-10, 10]$ and a time interval $\delta\tilde{t} = 0.001$ for a bright soliton solution with null velocity and $n_0 = 1$

The maximum diference between the norm at $\tilde{t} = 0$ and the norm of the evolving function was: $1.4.59786764218x10^{-9}$

2.2 0.5 velocity

We compute with $\tilde{v} = 0.5$ and two diferent time intervals: $\delta\tilde{t} = 0.001$ and $\delta\tilde{t} = 0.01$

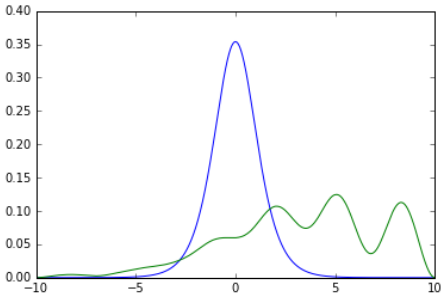

Figure 4: $|\Psi|^2$ *at time* $\tilde{t} = 0$ *in blue and at time* $\tilde{t} = 5$ *in green with* $\delta\tilde{t} = 0.01$

The maximum diference between the norm at $\tilde{t} = 0$ and the norm of the evolving function was: $3.06995195931x10^{-9}$

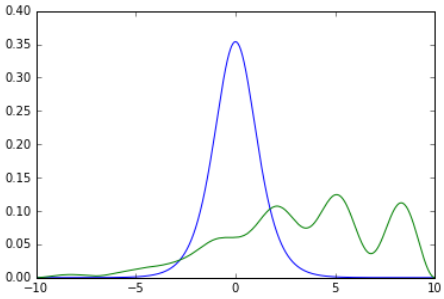

Figure 5: $|\Psi|^2$ *at time* $\tilde{t} = 0$ *in blue and at time* $\tilde{t} = 10$ *in green with* $\delta\tilde{t} = 0.001$

The maximum diference between the norm at $\tilde{t} = 0$ and the norm of the evolving function was: $3.45472594976x10^{-9}$

Here we have also computed the time that the program's been runing to obtain the result. For $\delta\tilde{t} = 0.01$ it was only $19.82s$ whereas the running time for $\delta\tilde{t} = 0.001$ it was $87.26s$ and yet there is no significant improvement on the result.

3 Grey soliton

We run the code for the grey solution for a spacing of $\Delta\tilde{z} = 0.01$ with $\tilde{z} \in [-10, 10]$ and a time interval $\delta\tilde{t} = 0.01$ and the results found are:

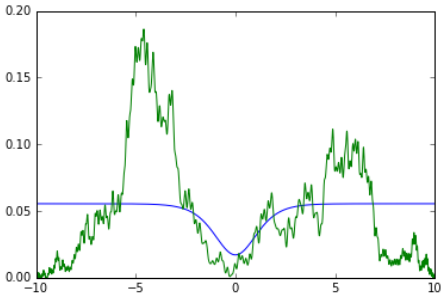

Figure 6: $|\Psi|^2$ *at time* $\tilde{t} = 0$ *in blue and at time* $\tilde{t} = 5$ *in green with* $\tilde{v} = 0.5$

The maximum diference between the norm at $\tilde{t} = 0$ and the norm of the evolving function was: $9.4415014253x10^{-5}$

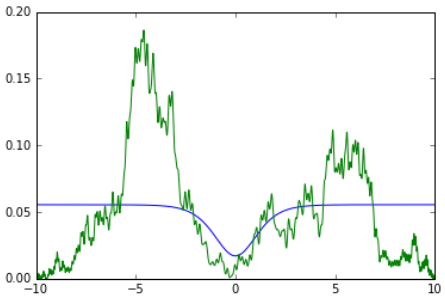

Figure 7: $|\Psi|^2$ *at time* $\tilde{t} = 0$ *in blue and at time* $\tilde{t} = 5$ *in green with* $\tilde{v} = 0$

The maximum diference between the norm at $\tilde{t} = 0$ and the norm of the evolving function was: $9.70332161562x10^{-5}$