The background of the slide is a light gray gradient, decorated with several realistic water droplets of various sizes. The droplets are rendered with soft shadows and highlights, giving them a three-dimensional appearance. They are scattered across the page, with some larger droplets near the top and bottom edges, and smaller ones in between.

# DYNAMICS OF BOSE-EINSTEIN CONDENSATES IN DIFFERENT RANDOM POTENTIALS

KHANG PHAM

MENTOR: DR. JUANA MORENO, SAMUEL KELLAR, KA MING TAM

# BEC IN RANDOM POTENTIALS EQUATION

$$i\partial_t\psi = \left[-\frac{\partial_x^2}{2} + V_{ho}(x) + V(x) + g|\psi|^2 - \mu\right]\psi$$

- $V_{ho}$  – Harmonic potential
- $V$  – Random potential
- $g|\Psi|^2$  – Interaction between particles
- $\mu$  – Chemical potential

# METHOD

- Finite Difference – a method for solving differential equations by approximating them with difference equations. For example,

$$f'(x_j) = \frac{f(x_{j+1}) - f(x_j)}{\Delta x} + O(\Delta x^2)$$

- Crank-Nicolson – a finite difference method.

$$\frac{f_j^{n+1} - f_j^n}{\Delta t} = \frac{1}{2} \left( \frac{f_{j+1}^{n+1} - 2f_j^{n+1} + f_{j-1}^{n+1}}{(\Delta x)^2} + \frac{f_{j+1}^n - 2f_j^n + f_{j-1}^n}{(\Delta x)^2} \right)$$

# HPX – HIGH PERFORMANCE PARALLEL

## ([HTTP://STELLAR.CCT.LSU.EDU/PUBS/HPX\\_1.PDF](http://stellar.cct.lsu.edu/pubs/hpx_1.pdf))

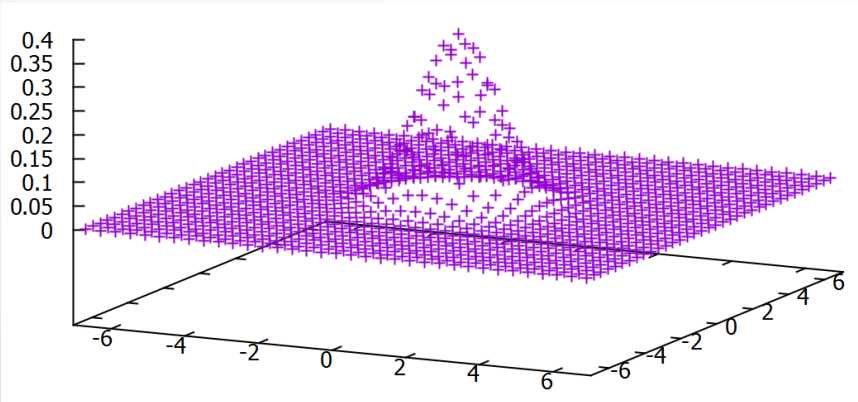
- HPX – a c++ library that distributes the works to different nodes of a cluster.
- HPX minimizes slow
  - **Starvation** occurs when there is not enough computation for the program to maintain high performance and utilize all resources
  - **Latencies** cause stoppage in the code due to the waiting for information to be received
  - **Overhead** is the work required to manage parallel actions
  - **Waiting for Contention resolution** is the time delays for different parts of the program to get an overshared information
- Improves slow in many ways, for examples:
  - Dataflow
  - Future

# PROCESS

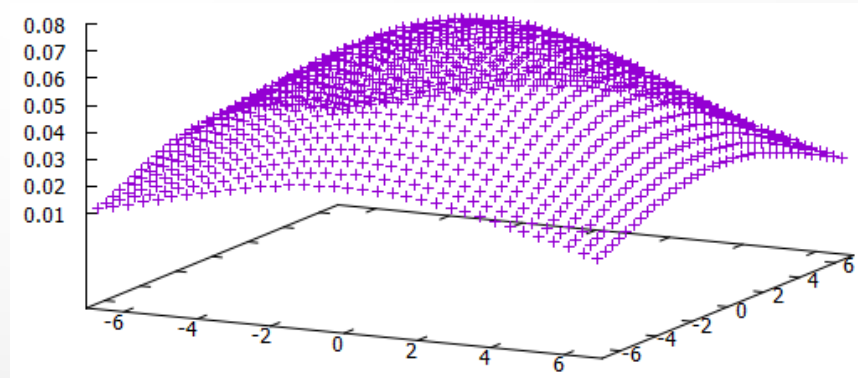
- To test the program, we solve for wave functions of different potentials such as
  - Zero potential
  - Harmonic potential
  - Harmonic potential with disorder

# SCHRODINGER EQUATION WITH NO POTENTIAL

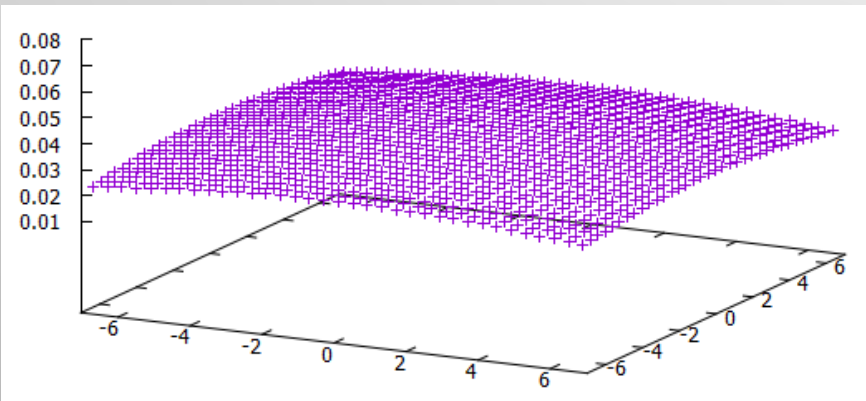
Probability amplitude at the earliest time



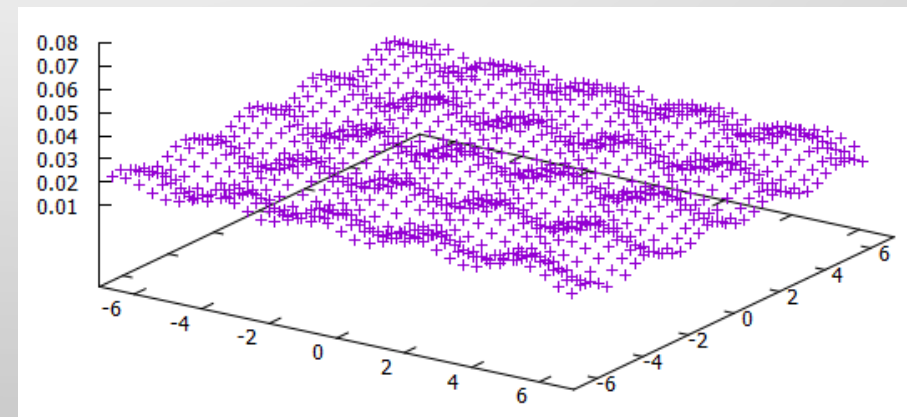
Probability amplitude after a fourth of the total time has passed



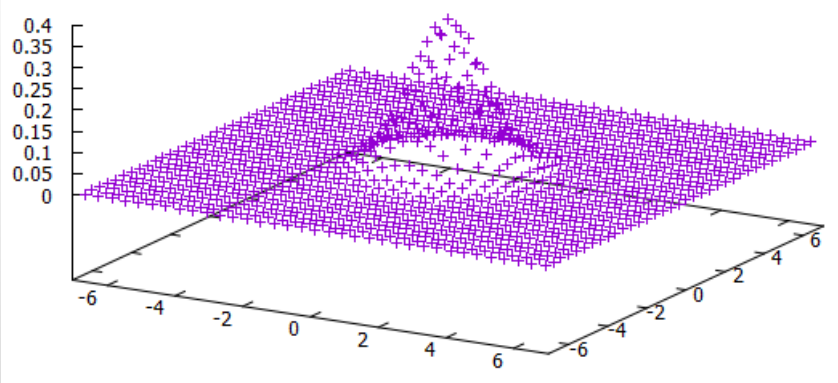
Probability amplitude after half of the total time has passed



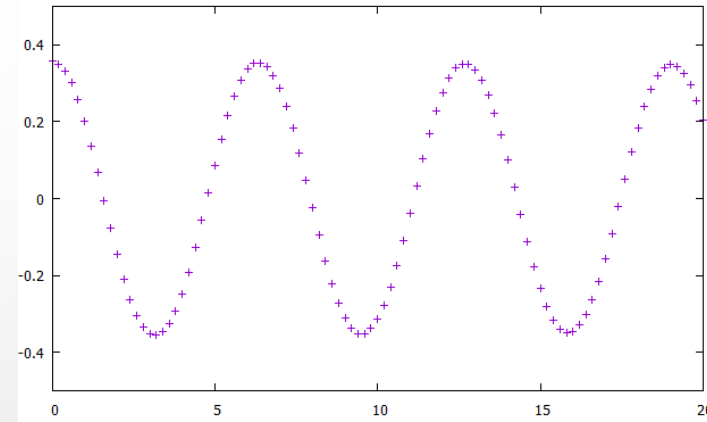
Probability amplitude at the latest time



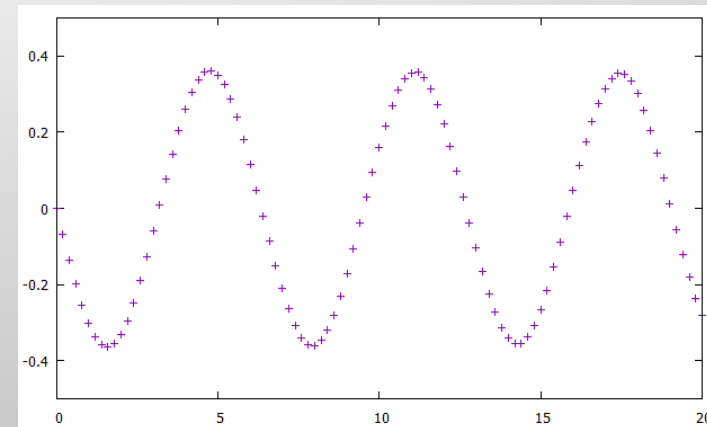
# SCHRODINGER EQUATION WITH HARMONIC POTENTIAL



The probability amplitude of the wave function over time.



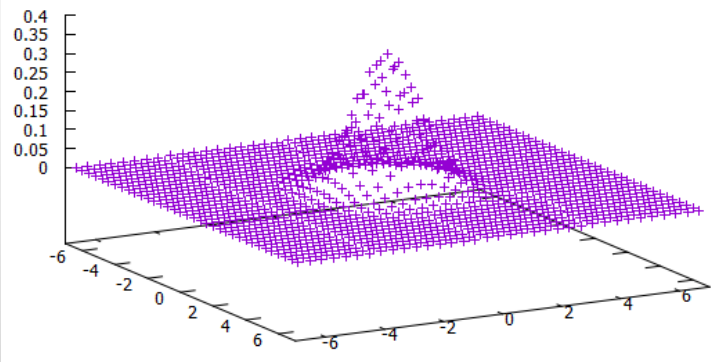
Real part of  $\Psi(0)$



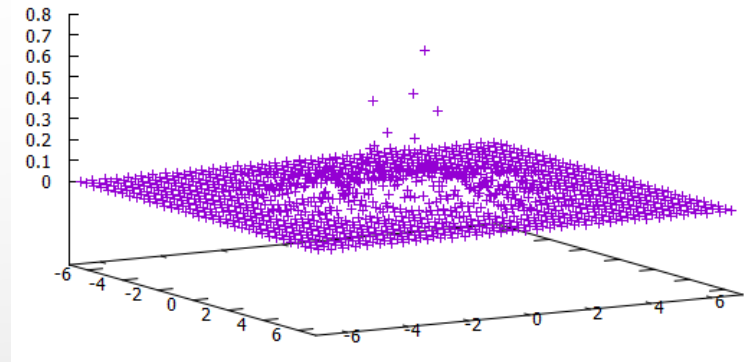
Imaginary part of  $\Psi(0)$

# SCHRODINGER EQUATION WITH RANDOM HARMONIC POTENTIAL

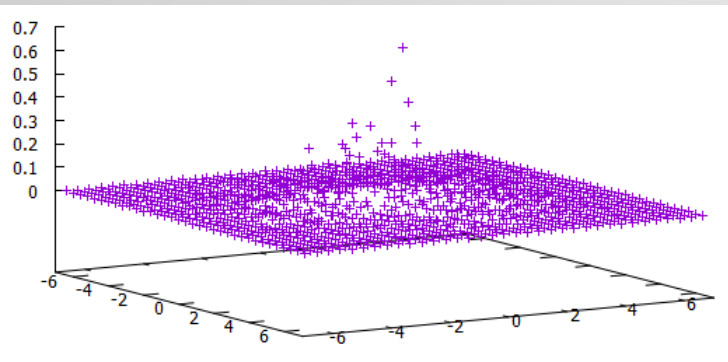
Probability amplitude at the earliest time



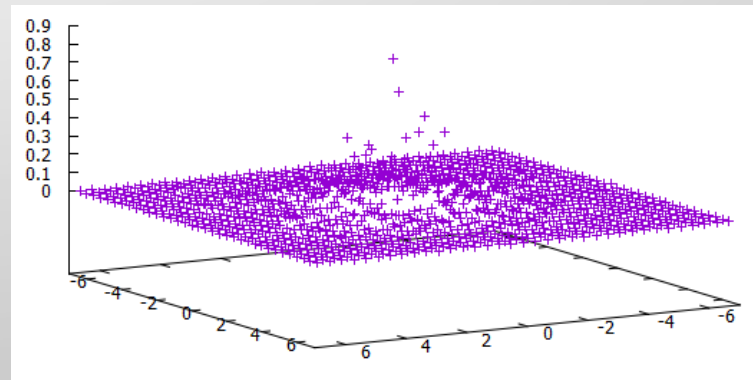
Probability amplitude after a fourth of the total time has passed



Probability amplitude after half of the total time has passed



Probability amplitude at the latest time





# SUMMARY

- THUS FAR, THE CODE IS FULLY FUNCTIONAL AND CAN SIMULATE MANY WAVE FUNCTION WITH DIFFERENT POTENTIALS.
- READY TO ADD IN NON-LINEAR TERM  $g|\Psi|^2$ .

The image features a light gray gradient background with several realistic water droplets of various sizes scattered in the corners. The droplets have highlights and shadows, giving them a three-dimensional appearance. The word "QUESTIONS?" is centered in the middle of the page in a bold, black, sans-serif font.

**QUESTIONS?**