Jones-Roberts soliton motion in a homogeneous BEC

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1 Introduction

In this example we simulate the precession of a single quantum vortex in a harmonic trap, and compare with the analytical result found by Fetter.

As simple model of this process, we start with the damped GPE

$$i\hbar\partial_t\psi = (1 - i\gamma)(L - \mu)\psi$$

where the GP operator is defined as

$$L\psi \equiv \left(-\frac{\hbar^2\nabla^2}{2m} + V(\mathbf{r}) + g|\psi|^2\right)\psi$$

and as usual the S-wave interaction parameter is $g = 4\pi\hbar^2 a/m$ for S-wave scattering lenght a.

The trap is chosen to be trivial

$$V(\mathbf{r}) = 0$$

The number $\gamma \ll 1$ describes irreversable interactons between condensate and noncondensate atoms, inducing condensate growth.

2 Loading the package

First, we load some useful packages, setting defaults for `Plots`.

```
using Plots, LaTeXStrings
gr(titlefontsize=12,size=(500,300),transpose=true,colorbar=false)
```

```
Plots.GRBackend()
```

Now load `FourierGPE`

```
using FourierGPE
```

In this example, we work in oscillator units. The units of length and time are $a_\perp = \sqrt{\hbar/m\omega_\perp}$ and $1/\omega_\perp$ respectively.

3 Initialize simulation

Initialize default sim with domain and grid parameters

```
L = (20.0,20.0)
N = (128,128)
sim = Sim(L,N)
@unpack_Sim sim;
```

4 Declare the potential

```
import FourierGPE.V
V(x,y,t)::Float64 = 0.0
```

```
V (generic function with 3 methods)
```

5 Thomas-Fermi initial state

```
ψ0(x,y,μ,g) = sqrt(μ/g)*sqrt(max(1.0-V(x,y,0.0)/μ,0.0)+im*0.0)
x,y = X

μ = 25.0
ψi = ψ0.(x,y',μ,g)
ϕi = kspace(ψi,sim)
@pack_Sim! sim;
```

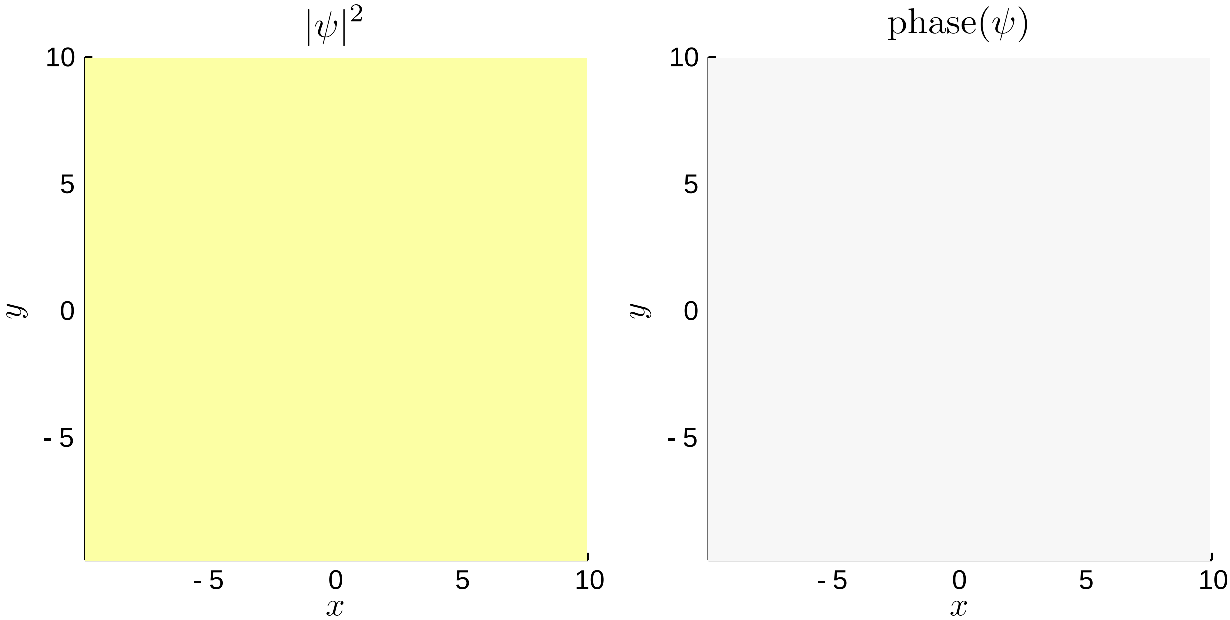
6 Imaginary-time evolution in k space

```
@time sol = runsim(sim);
```

```
1.362917 seconds (3.47 M allocations: 205.226 MiB)
```

Let's pull out the final state and verify that it is indeed the ground state of the harmonic trap:

```
ϕg = sol[end]
ψg = xspace(ϕg,sim)
showpsi(x,y,ψg)
```



7 Imprint Jones-Roberts soliton

We imprint a JR-soliton using the analytical solution

8 Set simulation parameters

Let's evolve for one period of Hamiltonian dynamics, as predicted by the Thomas-Fermi analysis:

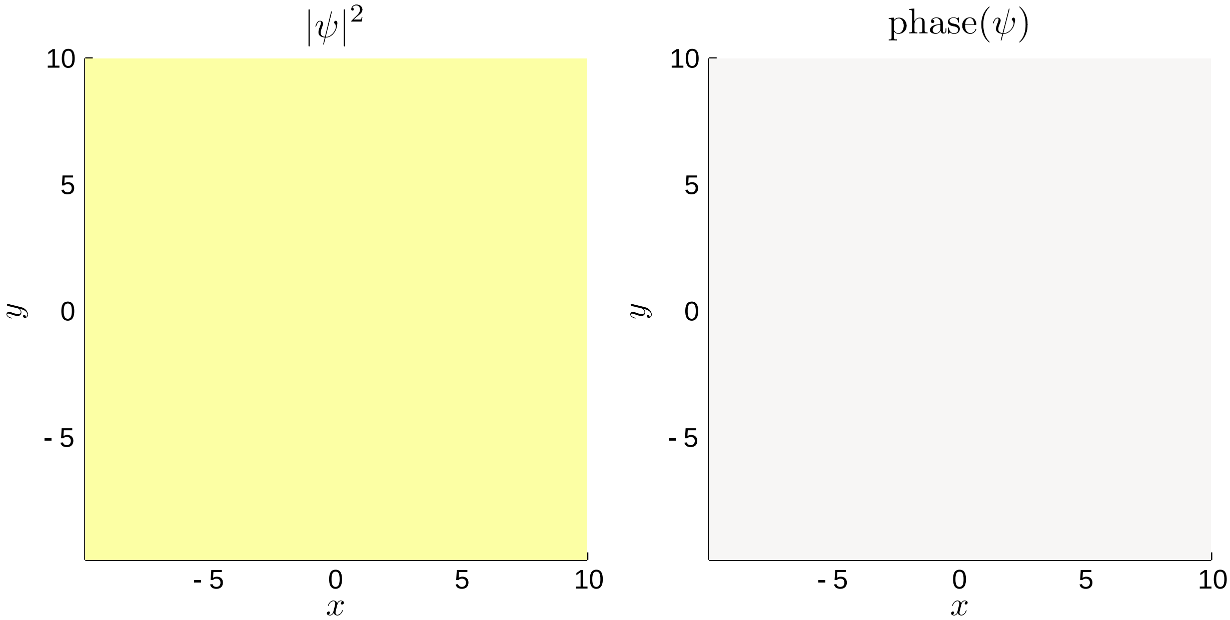
```
γ = 0.0
ϕi = kspace(ψg,sim)
@pack_Sim! sim; # write over previous sim  and reuse
```

9 Evolve in k space

```
solv = runsim(sim);
```

Pull out a state after some evolution

```
ϕf = solv[100]
ψf = xspace(ϕf,sim)
showpsi(x,y,ψf)
```



We can trim the last few frames to show one orbit

```
anim = @animate for i=1:Nt-6
    ψ = xspace(solv[i],sim)
    showpsi(x,y,ψ)
end;
```

and save the animation to the media folder

```
gif(anim,"./media/jrsoliton.gif",fps=30)
```

```
Plots.AnimatedGif("/Users/abradley/.julia/dev/FGPEexamples/media/jrsoliton.
gif")
```

discuss...