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# Rotation-induced chiral condensate

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# Outline

- Motivation
- Introduction of the BdG framework
- Inhomogeneous condensate
- Phase diagram
- Conclusions and outlook

# Motivation

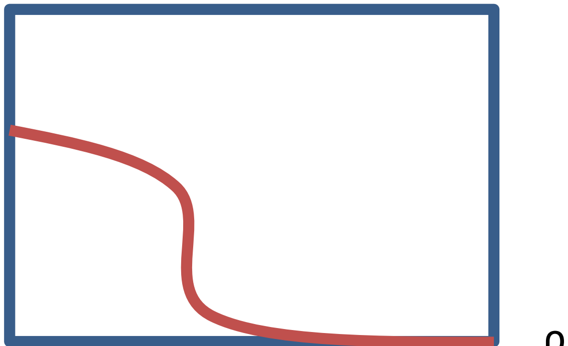
- Rotation or vortex is a common phenomenon in cold atom, heavy ion collision and neutron star.
- Non-triviality by considering the limit of speed and centrifugal effects.
- Requiring a  unified framework to deal with finite size and inhomogeneous effects.

# Assumptions and scheme

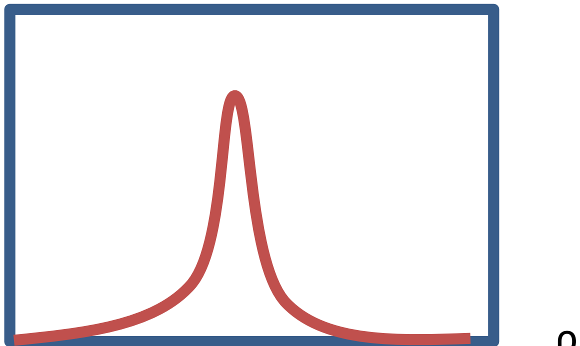
- Speed limit: $v = 2\,r^{-1}\int_0^r d\rho\rho\omega(\rho) < 1.$
- Space dependence or finite size.

~~Smooth condensate~~ → Self-consistent computation

Angular velocity profile

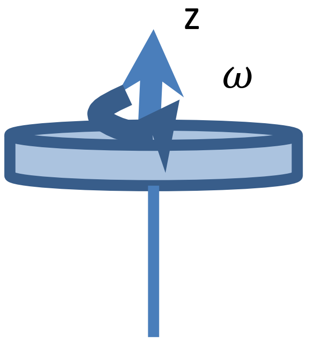



OR



# NJL model with rotation

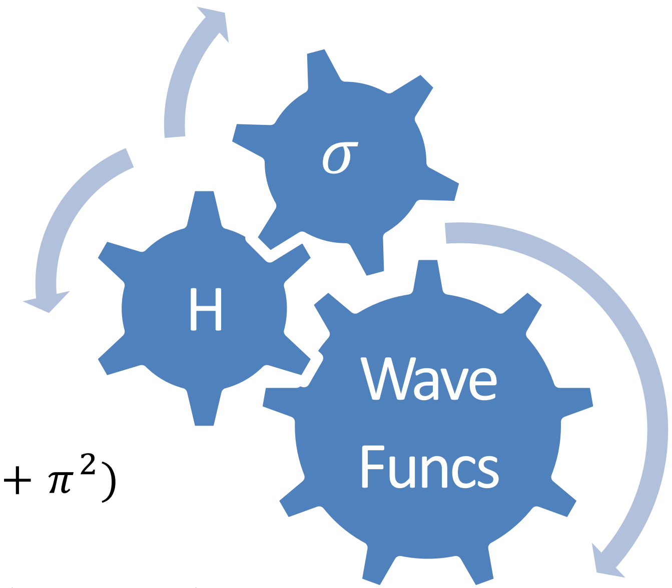
- Considering a rotating 2+1 D system at angular velocity $\omega$ . In its rest frame




$$H = H_0 - \vec{\omega} \cdot \vec{J}$$

- Renormalizable to avoid subtle regularization.
- Eigen states are unavailable for a general $\omega(\rho)$ .

# Self-Consistent Gap equation




- Mean Field approximation

$$\boxed{\sigma(\vec{r}) = -G\langle\psi\psi\rangle}$$

- Hamiltonian density

$$\mathcal{H}_{MF} = \psi^{\dagger}K[\sigma,\pi]\psi + \frac{G}{2}(\sigma^2 + \pi^2)$$

$$K[\sigma,\pi] = -i\gamma^0\vec{\gamma} \cdot \vec{\partial} - \vec{\omega}\cdot\vec{J} + \gamma^0(\sigma + i\gamma_5\pi)$$

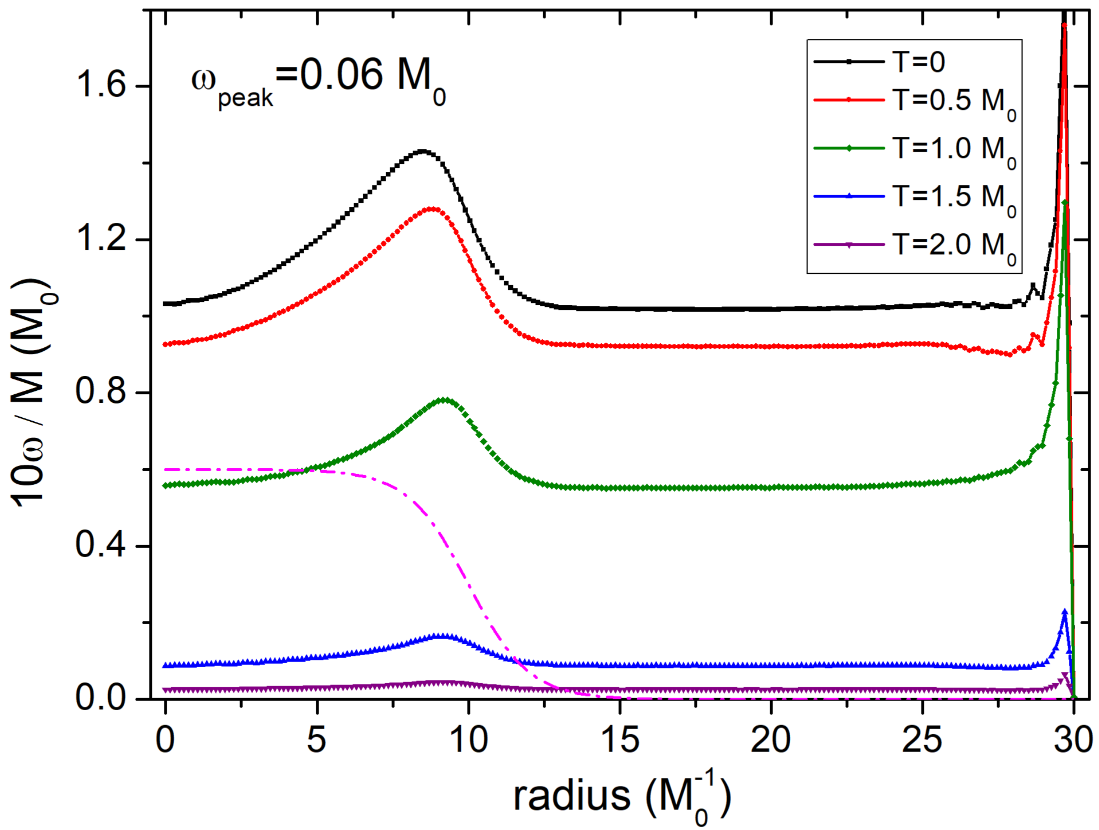
- Cylindrical symmetric basis

$$\psi_n^l(s) = \frac{1}{\sqrt{2\pi}}\sum_j c_{n,j}^{\uparrow}(s)\varphi_{j,l}^{s}(\rho,\theta)$$

- Brute-force diagonalization

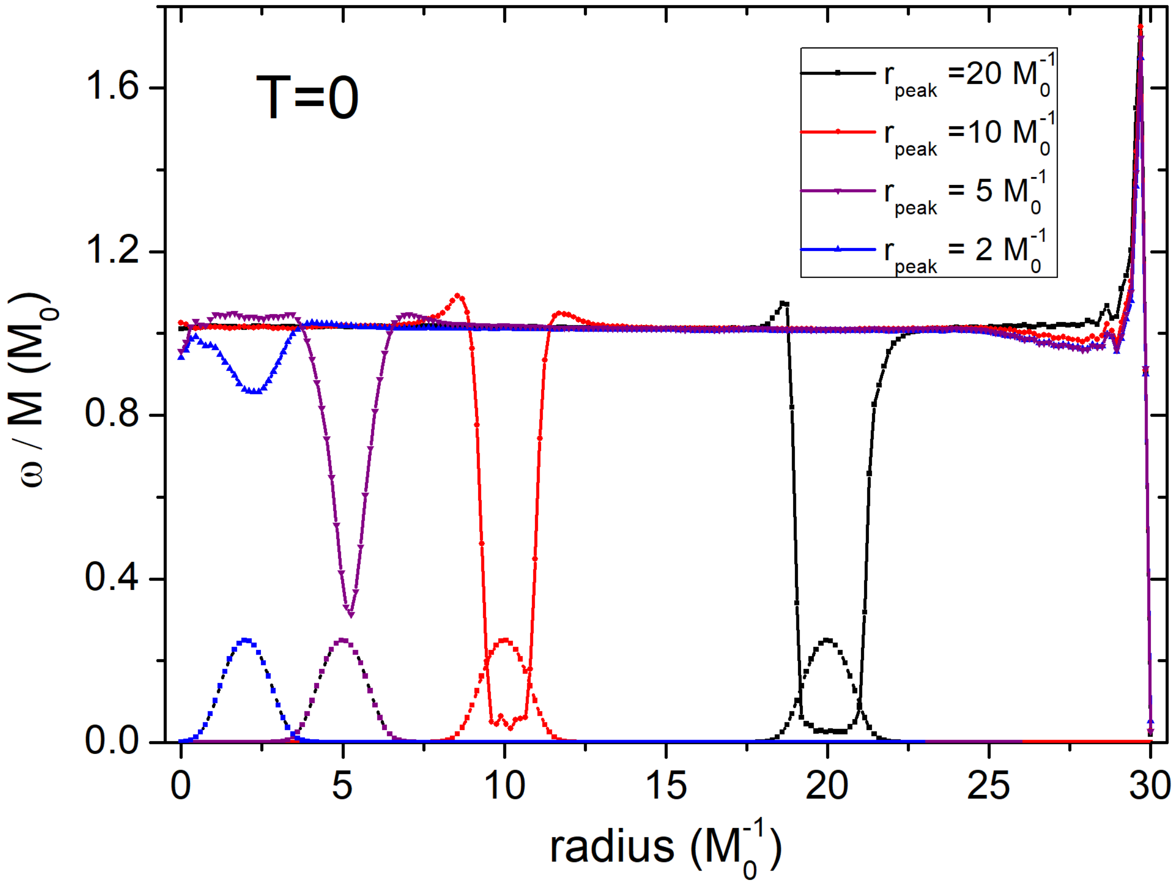
# Centrifugal Effects

## Condensate bump @ speed slope

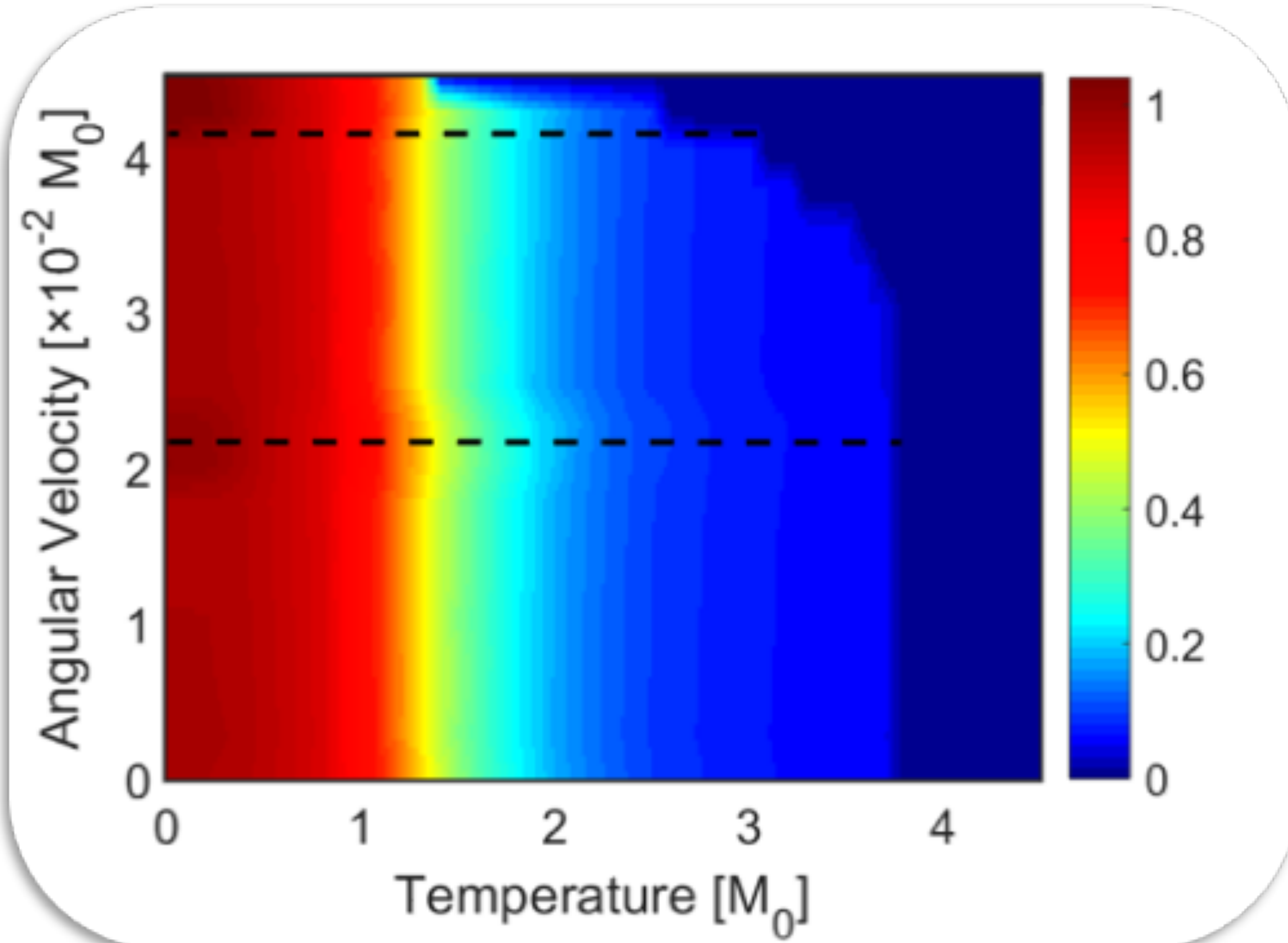


# Inhomogeneous rotating vacuum

## Condensate suppression @ large speed



# Phase diagram in Finite systems



# Conclusions & Outlook

- Fermion pairing studied with 2+1D NJL model in Self-consistent BdG framework.
- Centrifugal effects and Chiral condensate suppression are observed in rotating systems.
- T-$\omega$ phase diagram is roughly similar, but NOT equivalent to T-$\mu$ diagram in finite systems.
- More novel states(vortex states) are worth to exploring.

Thank you for your attention!

# Cookbook of PT study

- Choose the model
- Write down the interaction (Lagrangian density)
- Order parameter($\sigma$) & Approximation(Mean field)
- Calculate the free energy $Z = \int D\phi \, e^{-S[\phi,\sigma]} = e^{-\Omega[\sigma]V}$
- Minimize the free energy
- Gap equation for order parameter $f(\sigma, T, \mu, \ldots) = 0$

# Model choice

- Aiming at the chiral condensate.
- A relativistic model is necessary for quark matter.
- A fermionic model is better than a bosonic one.

✓ Nambu—Jona-Lasinio model is a suitable one.

- Mean field approximation as the 1st step

$$\mathcal{L} = \psi\left(i\gamma^{\mu}\partial_{\mu} - m_0 + 2G\langle\psi\psi\rangle_{\vec{r}}\right)\psi + \mu\,\psi\gamma^{0}\psi - G\langle\psi\psi\rangle^2 + \mathcal{L}_{rotation}$$