# Growth of Boson star

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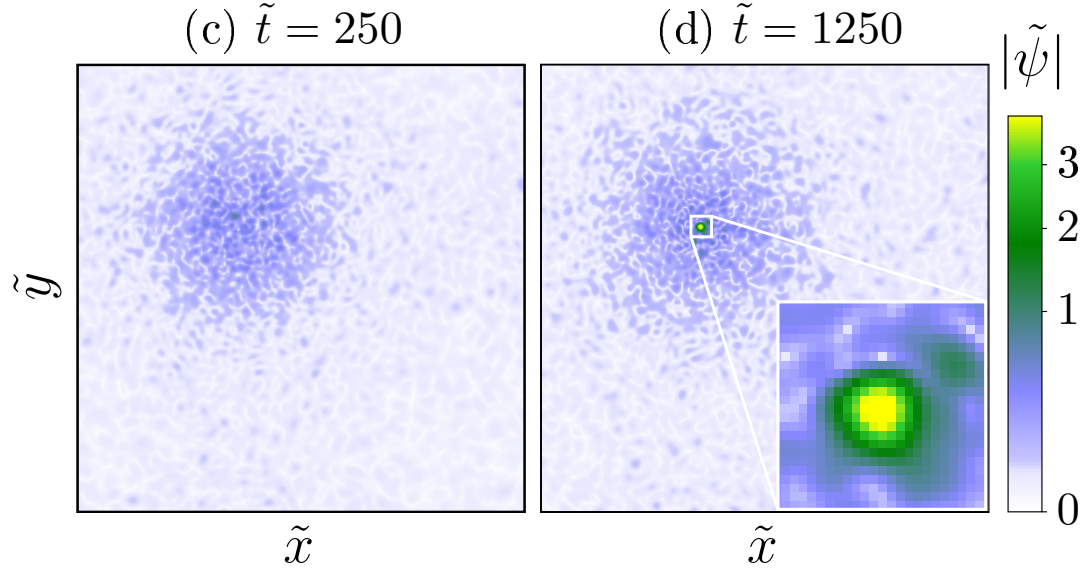
# Background

- Condensation of Boson star in minicluster
- Theoretical prediction of Boson stars' saturation in axion minicluster
- The negligible effect of self interaction in the condensation of boson star

# Condensation of Boson star in minicluster



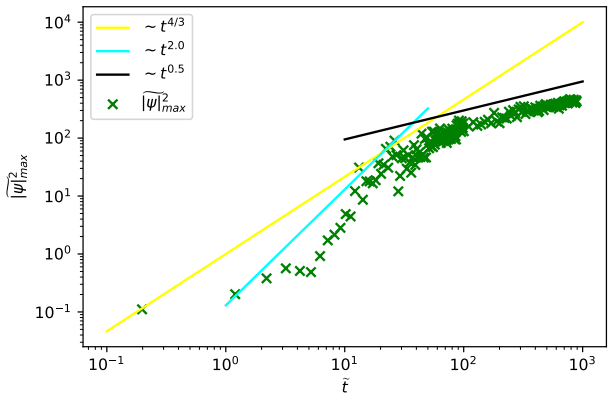

Axion miniclusters form

Boson stars will occur and grow in this axion miniclusters

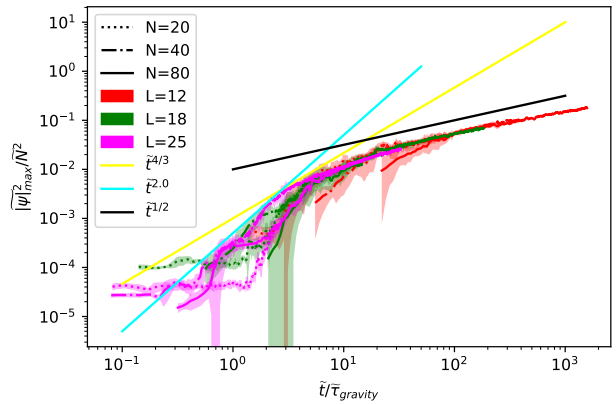
# Theory of Boson stars' saturation

- mass growth of boson star at early stage $\sim t^{1/2}$
- temperature of atmosphere surrounding boson star $\sim$ viral temperature of boson star
- growth rate drop to $\sim t^{1/8}$

# Simulation of Boson stars' saturation in axion miniclusters




Transaction from $\sim t^{1/2}$ to $\sim t^{1/8}$




Transaction is universal

# Axion with self interaction

- Gross–Pitaevskii-possion(GPP) equations:

  $i\frac{\partial}{\partial t}\psi = -\frac{1}{2m}\nabla^2\psi + mV\psi + g|\psi|^2\psi, \nabla^2 V = 4\pi G m\left(|\psi|^2 - n\right)$

- Gross-Pitaevskii (GP) equations:

  $i\frac{\partial}{\partial t}\psi = -\frac{1}{2m}\nabla^2\psi + g|\psi|^2\psi$

- $\widetilde{g} = g(M_{pl}v_0)^2$

# Theory of self interaction's effect

$$z = \frac{\tau_{gravity}}{\tau_{self}} \sim \frac{\sigma_{self}}{\sigma_{gravity}} \sim \frac{g^2 v^4}{16\pi^2 G^2 Log(mvL)}$$

- QCD axion in miniclusters:

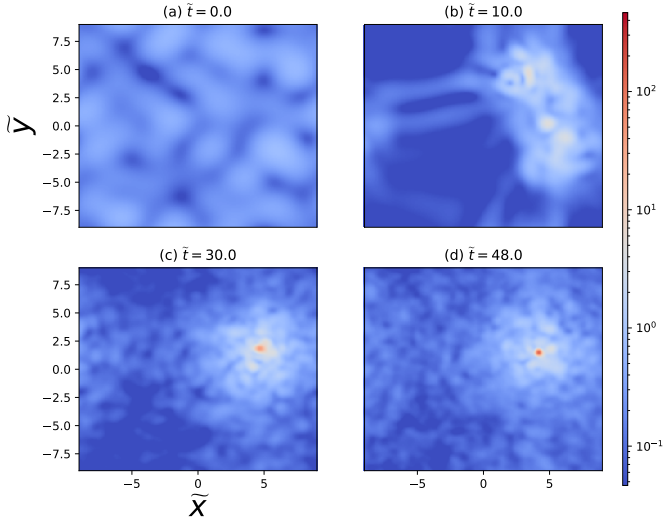
  $v \sim 10^{-9}$, $g \sim (-10^{-7} M_{pl})^{-1}$

- Fuzzy axions in dwarfs:

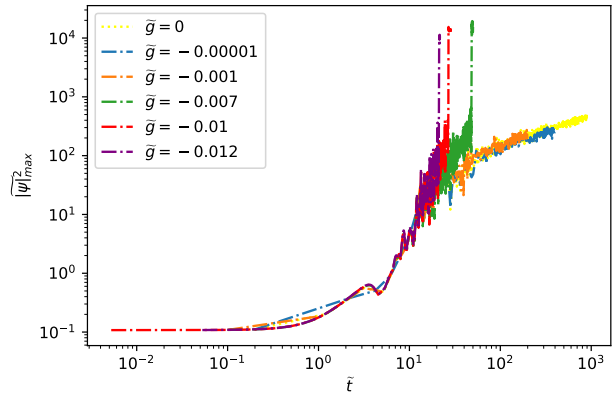
  $v \sim 10^{-4}$, $g \sim (-10^{-1} M_{pl})^{-1}$

$z \ll 1 \rightarrow$ self interaction is negligible

# Simulation with GPP equations

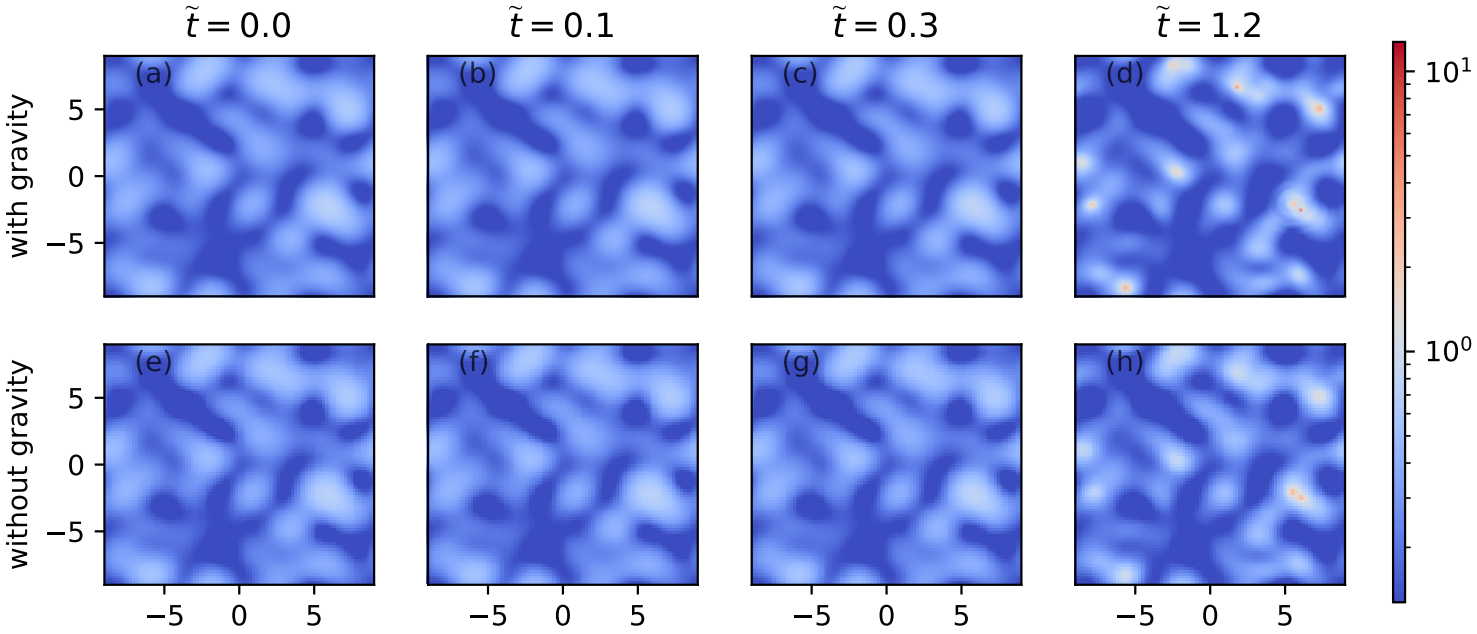



Similar process of minicluster's formation and boson star's condensation



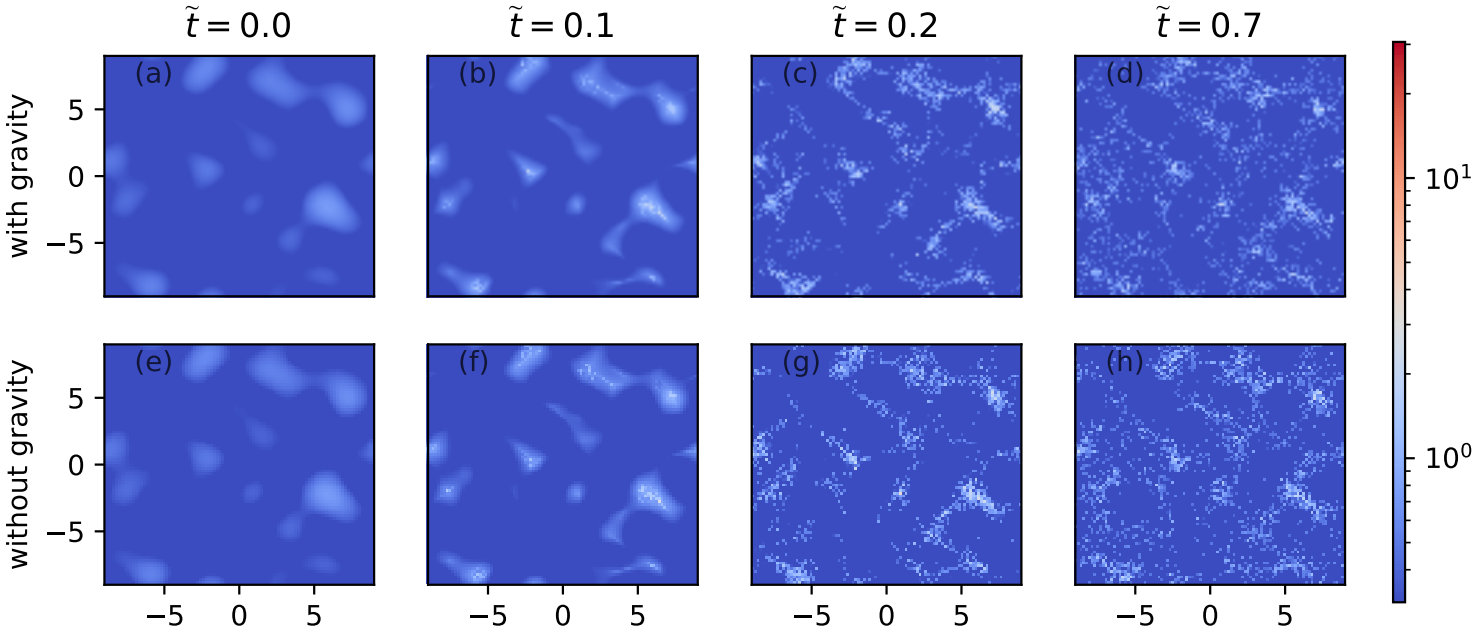

Similar maximum density evolution at the early stage but rapid growth at the end stage

# Powerful attractive self interaction



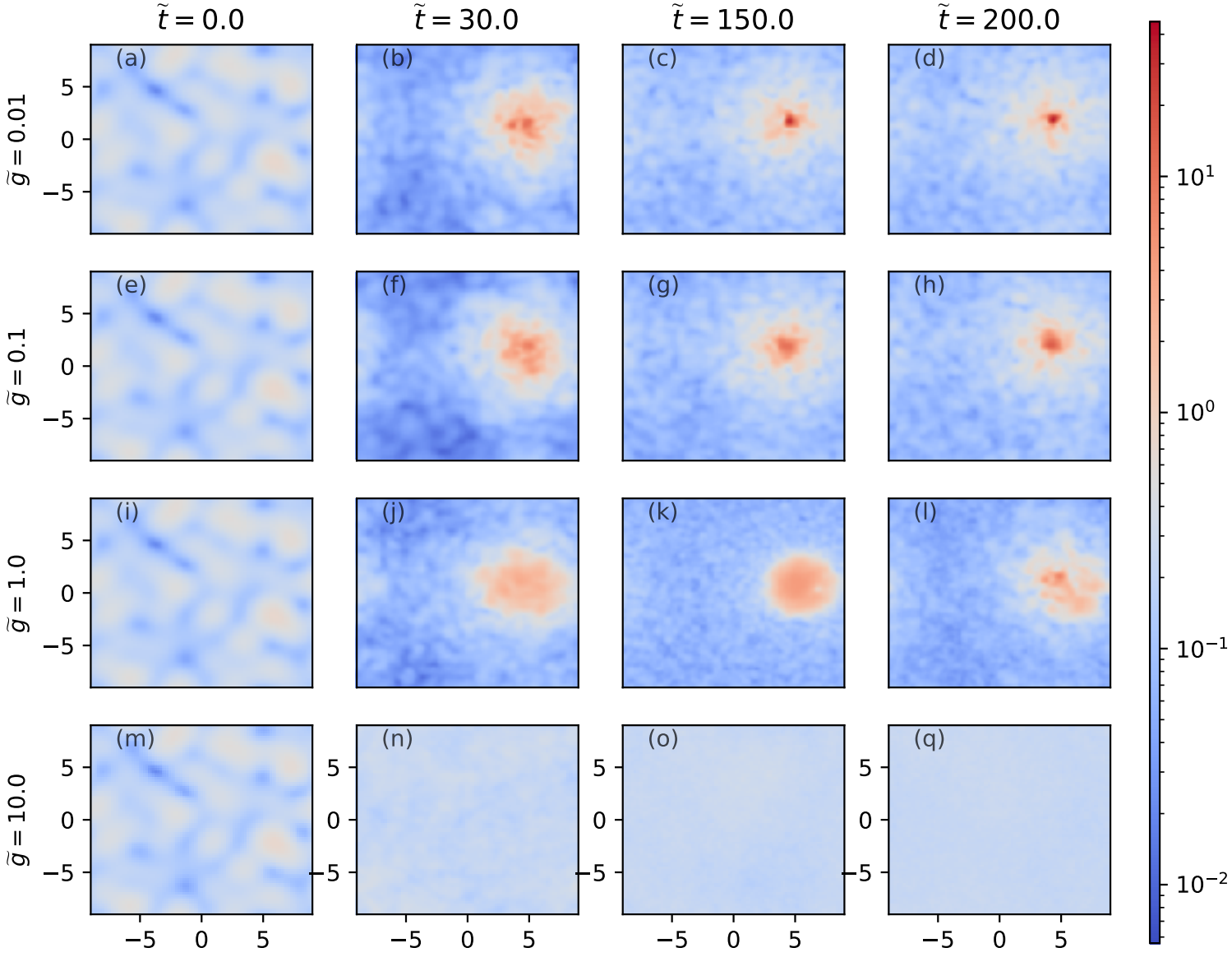

Simulating GPP equations and GP equations with $\widetilde{g} = -1.0$.

# Powerful attractive self interaction




Simulating GPP equations and GP equations with $\widetilde{g} = -80.0$.

# Opposite self interaction



# Opposite self interaction