Visualization of liquid Helium flows generated by an oscillating rectangular cylinder

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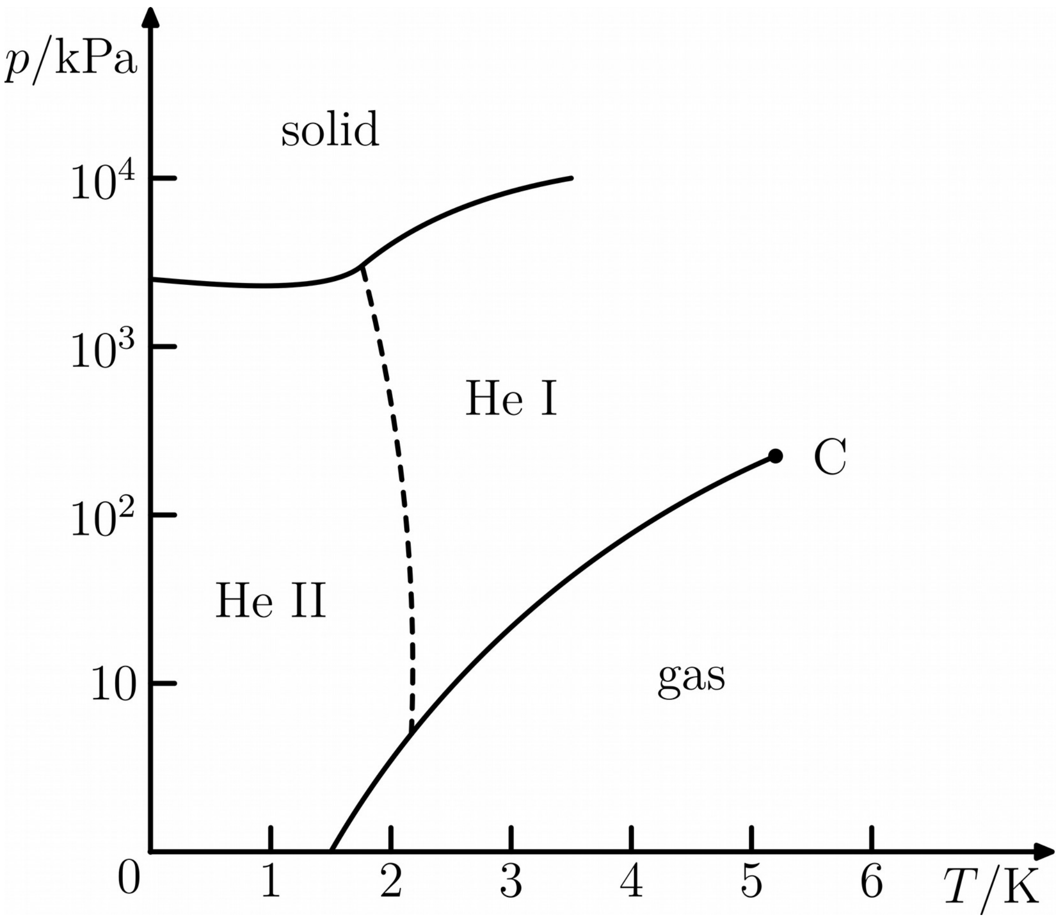
Liquid ^{4}He

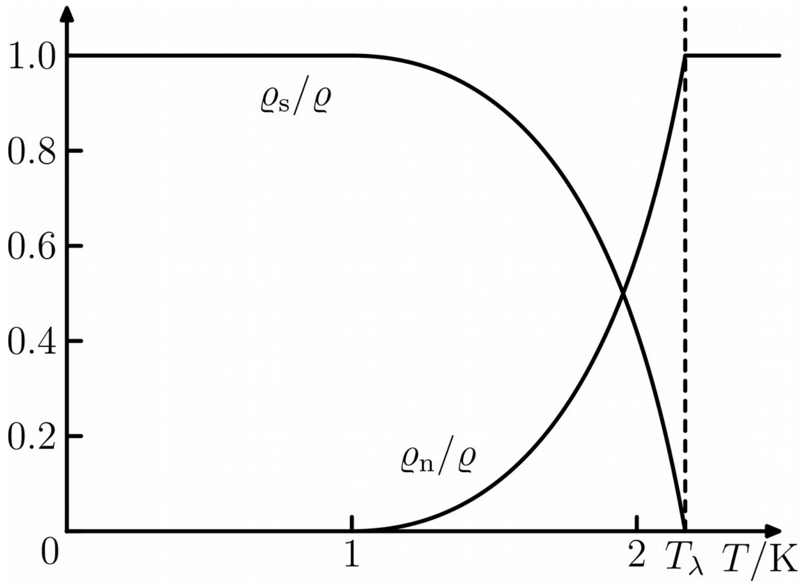
- Two phases of liquid ^{4}He
  - Normal phase (He I)
  - Superfluid phase (He II)

- Second-order phase transition (the lambda transition) at **2.17 K**, at the saturated vapor pressure



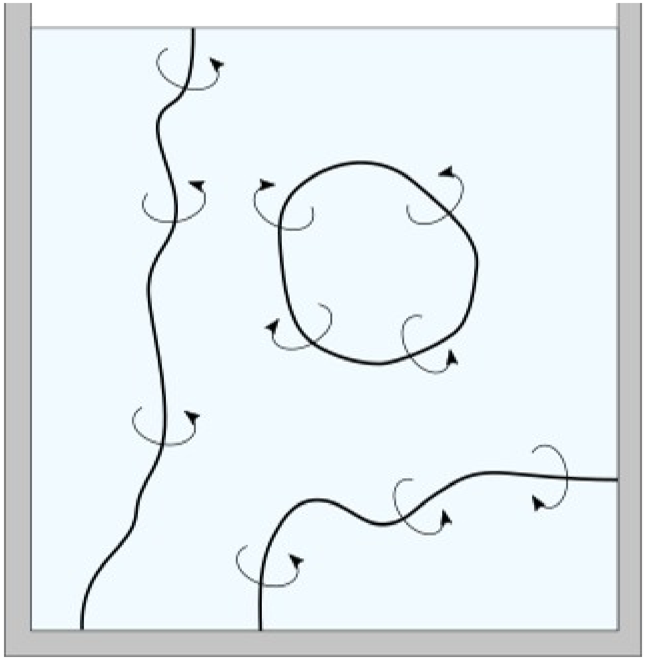
Superfluid phase of ^{4}He (He II)

- Phenomenological model (Landau):
  - Normal, viscous component
  - **Superfluid**, inviscid component
- Strong temperature dependence of the density of the components



- Quantized vorticity of the superfluid component

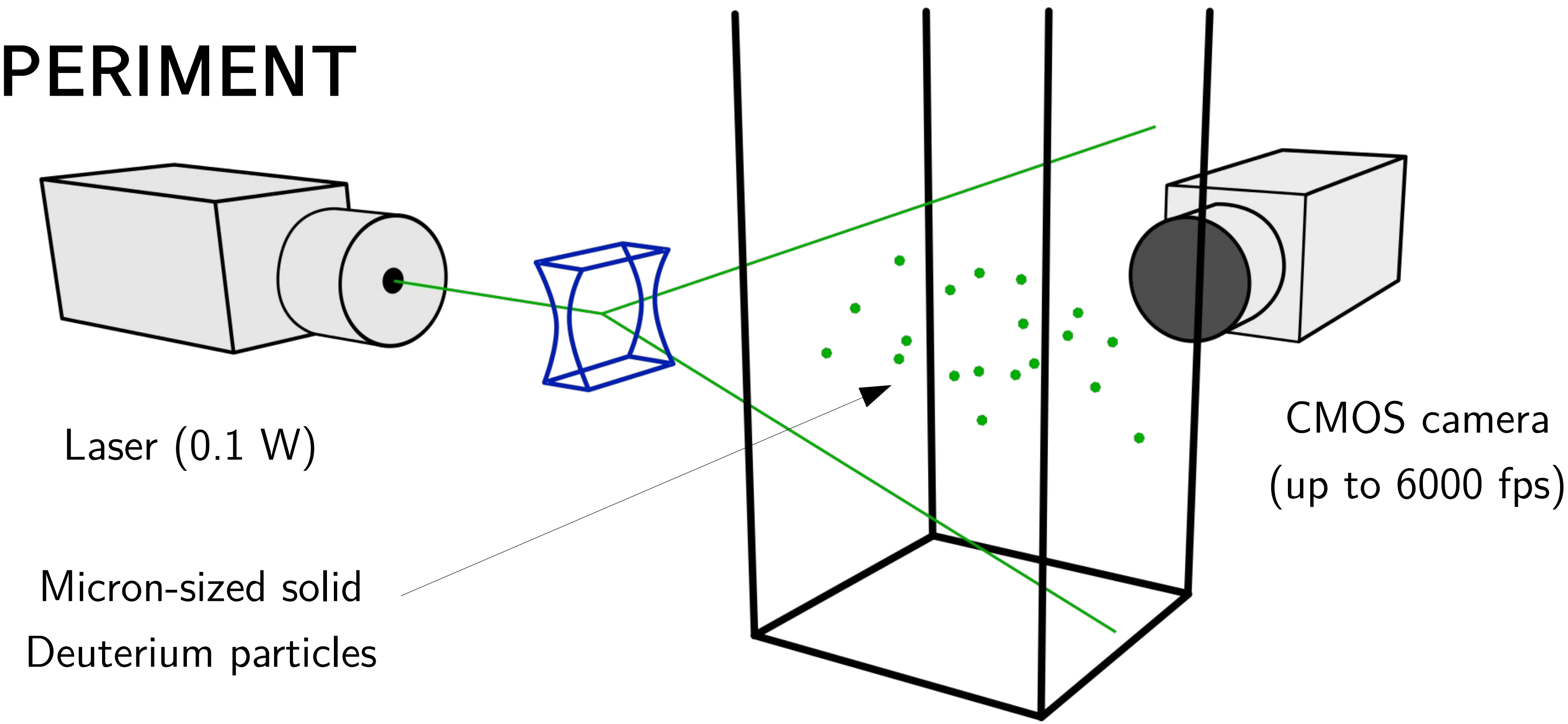
$$\kappa = \frac{h}{m_4} \approx 10^{-7}\mathrm{m}^2\mathrm{s}^{-1}$$



Macroscopic flows of He II

- Normal component $\rightarrow$ **Navier-Stokes equation**
- Superfluid component $\rightarrow$ **Euler equation**
- Coupling $\rightarrow$ **Mutual friction force**

EXPERIMENT



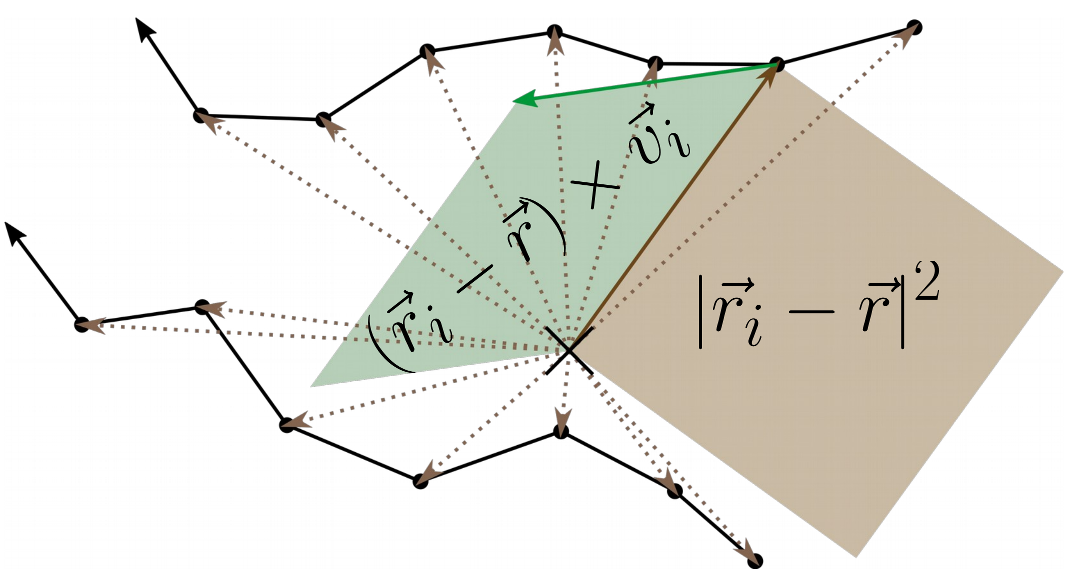
Sample run (He II, 1.3 K, 0.5 Hz)

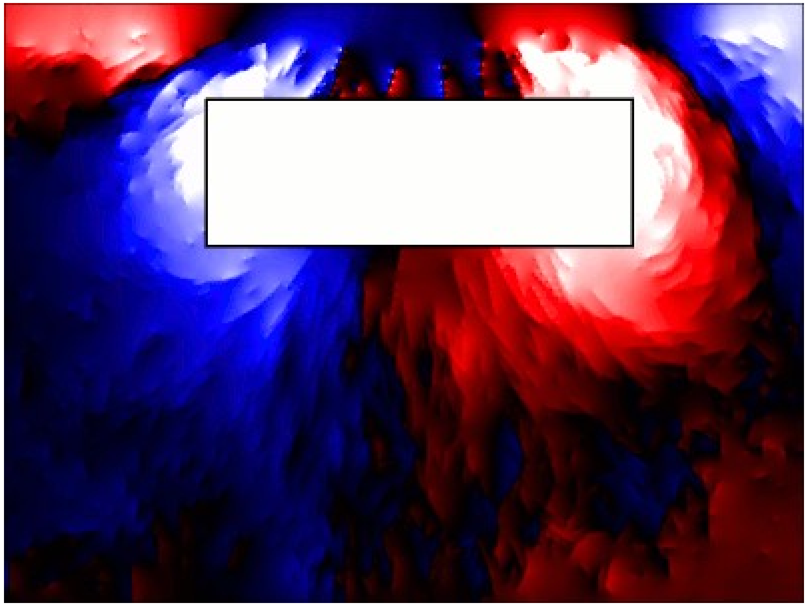
Data processing - Θ parameter

- The scalar "pseudovorticity" describes the magnitude of the vortices

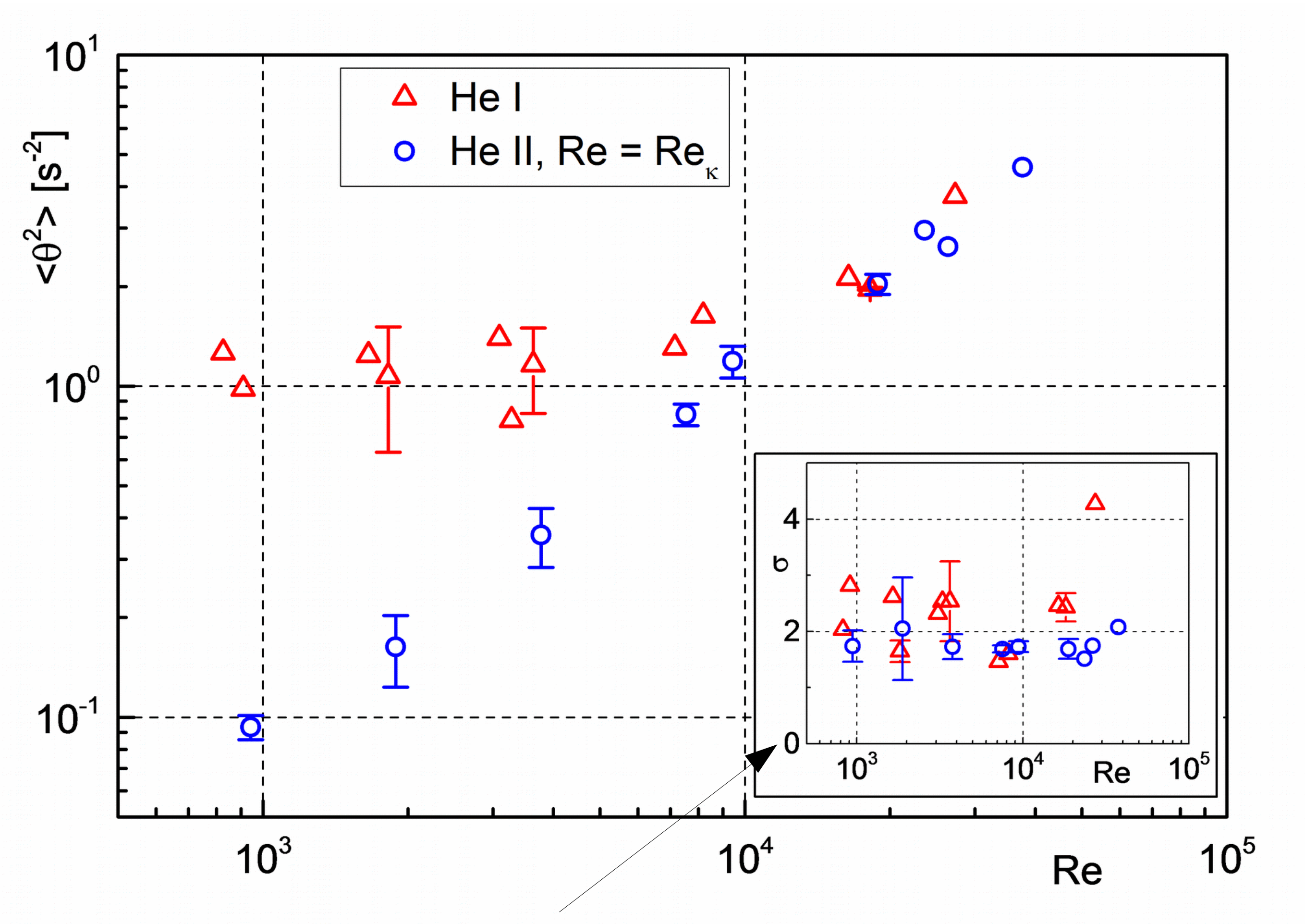
$$\theta(\vec{r},\varphi) = \left\langle \frac{(\vec{r}_i - \vec{r}) \times \vec{v}_i}{|\vec{r}_i - \vec{r}|^2} \right\rangle_{|\vec{r}_i - \vec{r}| < R_{\mathrm{M}};\ |\varphi_i - \varphi| < \Phi}$$

Θ Calculated for a suitably defined rectangular mesh





Results - $\langle\Theta^2\rangle$ vs. Re



Normalized standard deviation of $\langle\Theta^2\rangle$

Reynolds number

$$\mathrm{Re} = \frac{afW}{\nu}$$

For (viscous) **He I**

$$\nu = \frac{\mu}{\varrho}$$

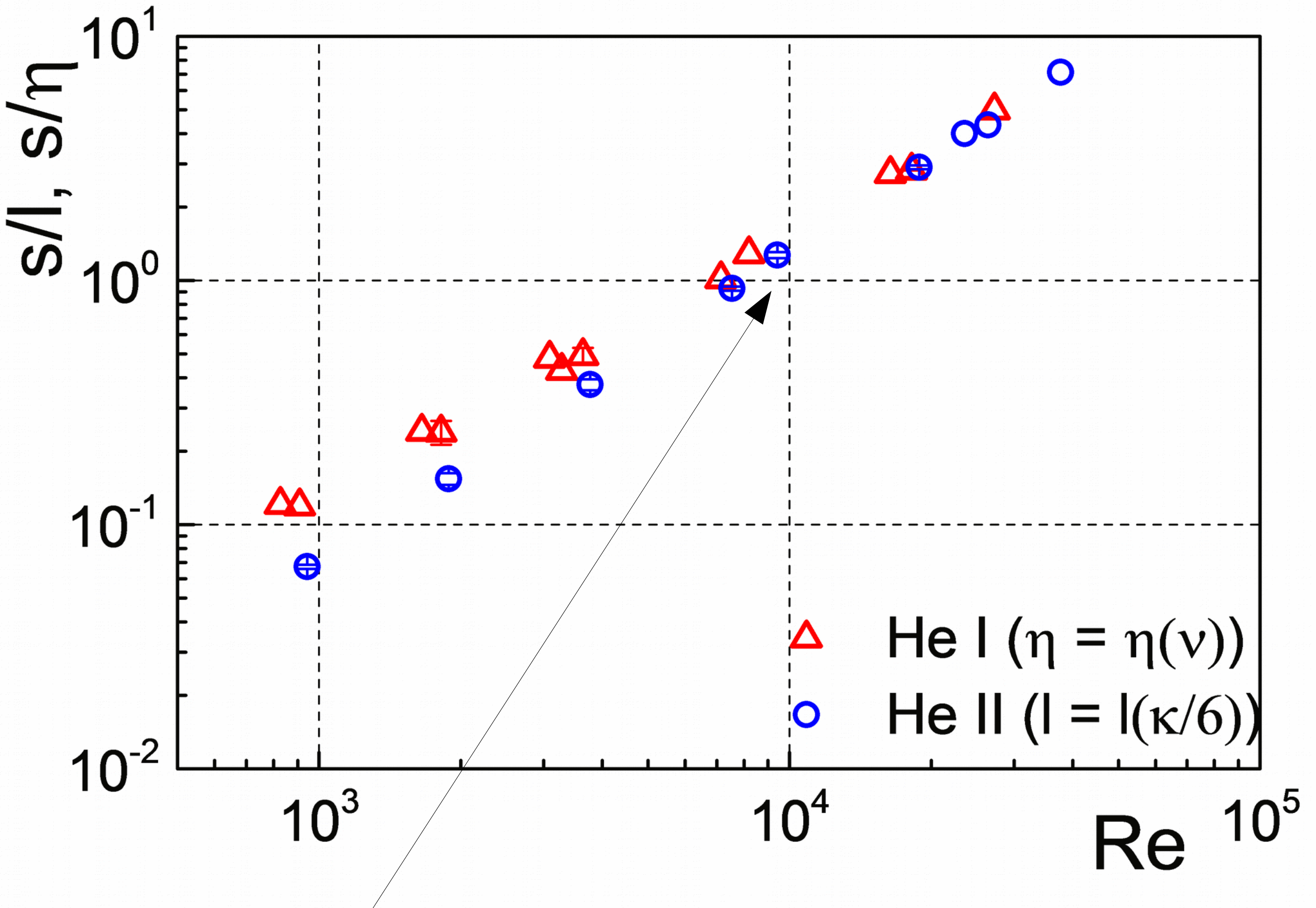
For (superfluid) **He II**

$$\nu \approx \frac{\kappa}{6}$$

Quantum of circulation

$$\kappa = \frac{h}{m_4} \approx 10^{-7}\mathrm{m}^2\mathrm{s}^{-1}$$

Interpretation – length scales



Resolution

$$s = \frac{a\omega}{f}$$

For (viscous) **He I**

$$\eta = \left(\frac{\nu^2}{\langle\theta^2\rangle}\right)^{1/4}$$

For (superfluid) **He II**

$$\ell = \left(\frac{(\kappa/6)^2}{\langle\theta^2\rangle}\right)^{1/4}$$

Same resolution as Kolmogorov length scale at $\mathrm{Re} = 10^4$

Summary

- Systematic study of He I and He II flows
- Mechanically driven flow $\rightarrow$ oscillating rectangular cylinder
- Custom-defined scalar quantity Θ suitable for vortex „strength“ characterization
- Similar macroscopic vortex pairs observed in (classical) He I and in (superfluid) He II
- He I and He II data yield **different values of $\langle \Theta^2 \rangle$** for Re $< 10^4$
  - Role of the parasitic effects (?)
  - Influence of the probed length scales (viscous or quantum)

Thank you for your attention

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