

Online Lecture Series held in Seoul, Korea

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After the original overseas dispatch plan to visit Switzerland was canceled due to the COVID-19 crisis, as a backup plan I decided to attend an online 3-day lecture series titled “Lectures on Gravitational Waves from the Early Universe” which was held by Chung-Ang University in Seoul, Korea during June 2-4, 2021. The lecturer was Dr. Kai Schmitz who works for CERN and is a leading researcher in the field.

I found this series to be highly beneficial because understanding the characteristics and behaviors of GWs in the early Universe is vital for my research, considering the fact that mine is about analyzing and simulating the behavior of scalar fields and gravitational effects at that epoch, and GWs are the key products produced from them that will link the original theory behind them to physical signals that we are able to observe today.

The lecturer did an excellent job covering the topic in a very comprehensive manner, from the basic properties of GWs in general relativity to various sources of GWs in the early Universe, all the way to the most recently announced NANOGrav signal, which all in all led the series to turn out to be a great opportunity for me to ramp up my knowledge of GWs in the early Universe.

Lastly, I'd like to thank my supervisor Prof. Kawasaki, the ALPS program, the organizers and the lecturer of the lecture series for letting me have this experience.

The image shows a screenshot of a Zoom meeting with a presentation slide. The slide is titled "Rough estimate of the peak frequency" and contains the following text and equations:

Recall, frequency today of a GW with wavenumber $k = x_k aH$ at production (during R

$$f \simeq x_k^{\text{RD}} \Omega_s^{1/2} \left(\frac{g_{*,s}^0}{g_{*,s}(T)} \right)^{1/3} \left(\frac{g_*(T)}{g_*^0} \right)^{1/2} \frac{T}{T_0} \frac{H_0}{2\pi}$$

Typical physical time and length scales during the phase transition:

$$\frac{k}{a} \sim \frac{2\pi}{c_{\text{light}} \Delta t} = \frac{2\pi}{c_{\text{light}} H \Delta t} H, \quad \frac{k}{a} \sim \frac{2\pi}{v_{\text{wall}} \Delta t} = \frac{2\pi}{v_{\text{wall}} H \Delta t} H$$

with velocity v_{wall} of the expanding bubble walls. GW spectrum expected to peak at:

$$f_{\text{peak}} \simeq 1.6 \text{ mHz} \left(\frac{1}{v} \right) \left(\frac{0.01}{H \Delta t} \right) \left(\frac{g_*}{100} \right)^{1/3} \left(\frac{T}{100 \text{ GeV}} \right)$$

- Fast (slow) phase transition at high (low) temperature \rightarrow high (low) frequency
- GWs from electroweak phase transition at $T \sim 100 \text{ GeV}$ in the LISA (mHz) band
- GWs from slow QCD phase transition at $T \sim 100 \text{ MeV}$ in the PTA (nHz) band

Reality: More than one peak from different processes, broad “domed” peaks, etc.
State of the art: Numerical lattice simulations, analytical models (sound shell model)

The slide is displayed in a Zoom window. The top of the window shows the meeting title "Kai Schmitz の公開授業「重力波」" and the name of the presenter, Kai Schmitz. On the right side, there is a vertical list of participants: Jae-hyeon Park, Francis Otani, Hyun Min Lee, Kai Schmitz, and Kunio Kaneta. The bottom of the window shows the Zoom control bar with icons for mute, video, chat, and other functions.

Figure 1: A scene from the online lecture.