STEPS Students Report

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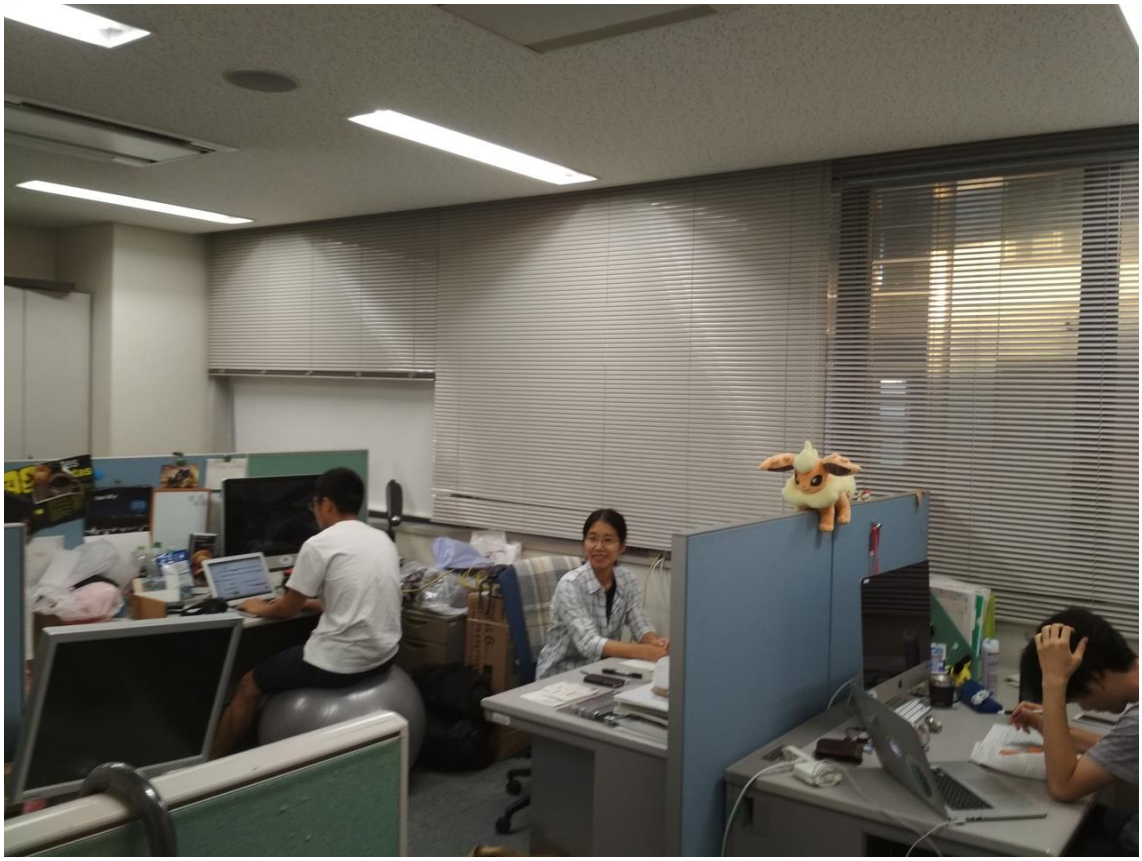
Participating in Students and Researchers Exchange Program in Science I joined Professor Teshima's CTA (Cherenkov Telescope Array) group in the Institute for Cosmic Ray Research (ICRR).



The aim of my study was investigation of sensitivity of CTA to parameters of the Extragalactic Magnetic Field (EGMF). As I wrote in my STEPS research plan, there are two main hypotheses of the EGMF origin [1]. According to the cosmological hypothesis, the primordial EGMF was produced in the early Universe during an electroweak phase transition or inflation. Therefore, probing the primordial EGMF one can obtain valuable information, including constraints on density of magnetic monopoles, parameters of axion-like particles and the neutrino magnetic dipole moment [2-3]. According to the astrophysical hypothesis, the EGMF was produced at late stages of evolution of the Universe by outflows from galaxies. Measurement of the EGMF spread by winds can constrain their properties and in this way shed light on the physics of the galactic

"feedback". So the problem of measurements of the parameters of the EGMF is really important and it is really interesting to obtain sensitivity of CTA for this kind of measurements.

My research plan was formulated as follows.
1) Acquaintance with the expected performance of CTA.
2) Preparation of a list of sources to observe with CTA.
3) Simulation of intergalactic electromagnetic cascades under various configurations of the EGMF.
4) Simulation of observable spectra using currently available observations of selected sources with atmospheric Cherenkov telescopes and the Fermi-LAT detector and fitting these model spectra.
5) Simulation of angular and temporal distributions measured by CTA.
6) Plotting areas of (B, λ) in which CTA will be sensitive to the EGMF parameters.
7) Comparing the sensitivity of CTA to the EGMF parameters with other gamma-ray instruments in the same conditions.

I consider results of my work in the ICRR as successful because I accomplished almost all points except for comparison of CTA's sensitivity and Fermi LAT's sensitivity. During the first week of my staying in the ICRR, I acquainted with details of the expected performance of CTA thanks to explanations of PhD student Yuki Iwamura. I was interested in possibilities of CTA to constrain the EGMF while observing variable sources so I figured out that a blazar Markarian-421 is one of the best sources for this purpose because it is located close to the Earth. I performed simulations of intergalactic electromagnetic cascades under various configurations of the EGMF from this source using a code of [4] and wrote a code that fit spectra of the source for every configuration and provide 3D (spectral energy, angular and temporal) analysis of observable gamma-ray emission. Thus I obtained the result that CTA can constrain the EGMF with accuracy in one order of magnitude while observing a very short flare in the blazar Markarian-421 at least in the range 10^{-19} G < B < 10^{-14} G (λ = 1 Mpc). I am planning to publish these results in a scientific journal as soon as possible.

References:
[1] Durrer R., & Neronov A. (2013) A&A Rev., 21(1).
doi: 10.1007/s00159-013-0062-7
[2] Long A. J., Vachaspati T. (2015) Phys. Rev. D, 91(10).

doi: 10.1103/physrevd.91.103522
[3] Medvedev M.V., & Loeb A. (2017) JCAP, 2017(06), 058-058.