STEPS Students Report

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During my stay in Japan, I have made a significant progress in my field of research, which is the study of the hadronic cascade model (HCM) of intergalactic gamma-ray propagation from extreme TeV blazars. HCM implies that the primary particles that are emitted from blazars are ultra-high energy (>1 EeV) protons and nuclei and on their way to the observer, they interact with the photons of Cosmic Microwave Background (CMB) and Extragalactic Background Light (EBL) creating secondary electrons, positrons and gamma-rays that initiate the development of intergalactic electromagnetic (EM) cascades. The main aim of this research is to constrain the contribution from intergalactic EM in HCM to observable gamma-ray emission of slowly variable blazars. Such models have recently attained some popularity [1-4].

In order to simulate the HCM, I use a propagation code, which is a hybrid code that propagates protons from the original redshift taking into account adiabatic, CMB (pair production & photopion) and EBL (only photopion) losses. Then it uses a precomputed database of EM cascade SEDs from gamma-rays with various energies.

In the course of my stay I was able to improve my code and extend it to analyze sources with redshifts up to z=5. In my previous work [5], I included only losses on the cosmic microwave background (CMB). In the present work, I also include photopion losses on the extragalactic background light (EBL). I used equation (1) of Berezinsky et al. [6] and assumed the EBL model of Gilmore et al. [7]. I have also been able to use the ICRR cluster to calculate the new EM cascade SED database for the model [7] and redshifts up to 5 using the new version of the ELMAG code [8], ELMAG 2.03 (previously I used a database for the model of Kneiske, Dole [9] and redshifts up to 0.3). This new version of the propagation code allows me to study promising sources with higher redshifts, such as a distant, powerful blazar PKS 1424+240 (redshift z=0.6 [10]). The code was tested to obtain SEDs for a set of primary proton energies and two redshifts (0.14 and 0.287) corresponding to the positions of two extreme blazars that were studied in my previous work [5].

I also had the opportunity to learn in detail about the upcoming Cherenkov Telescope Array (CTA) project that is being constructed in La Palma, Tenerife and help with the housing of its hexagonal mirrors inside the ICRR. I was also made an associate member of CTA and I hope that will facilitate the fruitful collaboration and joint research between my laboratory and ICRR. In addition, I have participated in the ICRR spring school for bachelor students and helped organize a pulsar analysis exercise for the students of the school using the Fermi-LAT data. The students have obtained the data for three well-studied pulsars (Crab, Geminga and Vela) for different time periods and analyzed their periodicity. The main purpose of the exercise was for them to find irregularities in the periodicity of pulsars, so-called 'glitches', and analyze them. It was a very fruitful and fun experience and I am glad that I could be part of it and learn much about pulsars from the specialists of that area.

Finally, I am grateful for the opportunity to learn more about Japanese culture and traditions and take a very comprehensive albeit short course of Japanese language.

References

1. W. Essey & A. Kusenko, APh, 33, 81 (2010)
2. W. Essey et al., Phys. Rev. Lett., 104, 141102 (2010)
3. W. Essey et al., ApJ, 731, 51 (2011)
4. K. Murase et al., ApJ, 749, 63 (2012)
5. T.A. Dzhatdoev et al., A&A, 603, A59 (2017)

6. V.S. Berezinsky et al., Phys. Rev. D, 74, 043005 (2006)

7. R.C. Gilmore et al., MNRAS, 422, 3189 (2012)

8. M. Kachelriess et al., Comp. Phys. Comm. 183, 1036 (2012)

9. T.M. Kneiske & H. Dole, A&A, 515, A19 (2010)

10. A.C. Rovero et al., A&A, 589, A92 (2016)