# Cosmic Neutrinos and Multi-messenger Workshop ”CosNuMM2019”

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Tsung-Dao Lee Institute (East wing of Pao Yue-Kong Library)

# Book of Abstracts

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## Atmospheric neutrino flux calculation at low energies

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The precise calculation of atmospheric neutrino fluxes in the low-energy range at JUNO is presented, where the calculating scheme is based on the method in Honda et al. Phys. Rev. D 92, 023004 (2015), but with more precise local information on the geomagnetic field, air density and mountain profile. To reduce the associated flux uncertainties, a careful consideration of the muon decay and capture inside the Earth is included.

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## Brace for supernova neutrino burst by waveform compression

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The observation of neutrino burst from SN1987A provided invaluable insights on star evolution and essence of neutrinos. Because of the establishment of SuperNova Early Warning System(SNEWS), a global network of observatories has been formed for the next galactic supernova. Nevertheless, it remains a big challenge to transfer and store the complete data stream from PMT and FADC systems of neutrino and dark matter detectors.

We developed an effective algorithm that provides compression for PMT voltage readout waveforms by a library of orthogonal basis and information theoretic critera. In simulated dataset, our algorithm gives a 50 times reduction on the size of data while preserving full waveform features. We believe that efficient algorithms will largely empower those neutrino and dark matter detectors by improving their capability to gather supernova burst neutrino signals before falling back into degenerate emergency mode.

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## Pre-supernova neutrino observation in JUNO

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Jiangmen Underground Neutrino Observatory (JUNO) is one of the next-generation neutrino experiments under construction, designed with a 20 kt large liquid scintillator detector. Prior to the core-collapse of the massive stars with mass larger than 8 solar mass, the increasing sub-MeV neutrinos produced through thermal and weak nuclear processes enables their observation in JUNO. In this talk, we explore the observable signals of these pre-supernova (pre-SN) neutrinos with the inverse beta decay (IBD) and the neutrino-electron elastic scattering reactions in JUNO. The sensitivity to pre-SN neutrinos as well as the pre-SN pointing ability in JUNO is quantified with the

IBD events. Throughout, the well-known possible supernova candidate, Betelgeuse, is taken as the reference astrophysical object. For the next nearby galactic SN, the pre-SN detection could act as the early alert for the imminent core-collapse SN, reserving time for the follow-up multi-messenger observation.

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## Probing fundamental laws of physics from Multi-Messenger astronomy

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New high energy astro-particle physics experiments will provide a new whole avenue towards innovative explorations of new physics beyond the Standard Model and Quantum Gravity. In this talk, we will discuss several exotic phenomena which can be probed from next generation of experiments such as LHAASO and JUNO and further other cosmic rays facilities, in a multi-messenger strategy. The most exciting and unexpected frontier is on searching any footprints of Exotic Compact Objects, hunting for Gravastars, Wormholes, Fuzzballs and Boson Stars, beyond standard General Relativity Black Holes.
Cross-comparisons among high energy nuclei, gamma rays, neutrinos and gravitational waves signals can highly improve our understanding of the Black Hole event horizon, possible suggesting a way-out from Firewall and Hawking paradoxes.

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## Two-zone models for the multi-messenger emission from the blazar TXS 0506+056

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A high-energy muon neutrino event, IceCube-170922A, was recently discovered in both spatial and temporal coincidence with a gamma-ray flare of the blazar TXS 0506+056. We propose the multi-messenger emission of the blazar flare can be well explained in two-zone models, with an inner blob inside of or close to the broad-line region (BLR) and an outer one well beyond the BLR. We compare our model with one-zone models discussed in previously literature and argue that differentiating between such scenarios will become possible with next-generation neutrino telescopes, such as IceCube-Gen2.

**New Physics & Multi-messenger / 7**

## Subleading Corrections to Heavy Higgsino and Wino Direct Detection

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In the heavy WIMP limit, the cross sections for Higgsino-like particles scattering on nucleons is severely suppressed by an amplitude level cancellation, making it important to assess the impact of formally subleading effects. The power correction of order $m_W/M$ to the heavy WIMP limit is computed for general electroweak doublet dark matter candidates, and a model of nuclear modifications to the free nucleon cross section is evaluated. The direct detection signal in the pure Higgsino limit remains below neutrino backgrounds for WIMPs in the TeV mass range. Corrections to the pure Higgsino limit are parameterized by a single parameter in the heavy WIMP expansion through $calO(1/M)$. Conditions on this parameter to yield significant cross section enhancements are investigated. Nuclear corrections are applied also to the heavy Wino case, completing the investigation of combined subleading effects from perturbative QCD, $1/M$ power corrections, and nuclear modifications.

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# Multi-Messenger Trigger System of JUNO

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The Jiangmen Underground Neutrino Observatory (JUNO) is a 20 kton liquid scintillator detector aiming to measure neutrino mass hierarchy. With its large target mass, low threshold and excellent energy resolution, JUNO can be a powerful neutrino telescope. To fully exploit its ability of observing astrophysical neutrinos, we are developing a multi-messenger trigger system for JUNO, trying to expand the observe energy window by further lowering the trigger threshold, and to search for transient astrophysical neutrino signals (like supernovae, neutron star mergers, etc.) by implementing Bayesian blocks algorithm on the trigger. In this talk, I will introduce our work and progress on the multi-messenger trigger system.

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# Constraints on diffuse high energy neutrino flux from Star-forming Galaxies

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If star-forming galaxies could accelerate cosmic ray to very high energies, high energy neutrinos and gamma-ray photons will be produced during cosmic ray propagation. Considering the gamma-ray point sources below the detection threshold, the source count distribution above 50 GeV places an upper limit on non-blazar component of the EGB measured by Fermi-LAT. Keith Bechtol et al. found a strong tension between the upper limit and the models that considering star-forming galaxies as the dominant sources of diffuse neutrino flux observed by IceCube.

In our work, we use the direct measurement of gamma-ray optical depth due to EBL to reduce the model dependent uncertainties brought by EBL model in Keith Bechtol et al 2017. We study on two neutrino emission spectra: single power law with exponential cutoff and broken power law with

exponential cutoff. For single power law $dN/dE \propto E^{-\gamma}$, the upper limit of neutrino flux at 100 TeV is compatible with 95.4% confidence region of the best fit parameter(assuming a single power law) to through-going track events but is lower than the 68.3% confidence region. For broken power law, we choose the same broken energy(25 TeV) in Keith Bechtol et al 2017 and test the spectral index $\gamma_1$ of lower energy band from 2.0 to 2.7. We find that the upper limit of neutrino flux at 100 TeV will be lower than the 95.4% confidence region of the best fit parameter if $\gamma_1 > 2.2$. We also try a new broken energy at 120 TeV. Such a sensitivity to low energy spectral index, however, does not change too much.

According to our work, the possibility that star-forming galaxies are dominant sources of diffuse neutrino flux can not be excluded, if we don't have a preference on the best fit parameters to different data sets. If there is softening above a certain energy around 10 to 100 TeV in neutrino spectrum, we have to get a very hard spectrum below such energy in the cosmic ray acceleration and neutrino production models.

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## Greetings

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