Cluster of Excellence Precision Physics, Fundamental Interactions and Structure of Matter
PRISMA

Mainz Institute for Theoretical Physics

Supernova Neutrino Observations: What can we learn? What should we do?

Organized by Hans-Thomas Janka (MPI for Astrophysics), Irene Tamborra (NBI, University of Copenhagen), Michael Wurm (JGU Mainz) and Lutz Köpke (JGU Mainz).

9 -13 October 2017

The experimental landscape for low-energy neutrino astronomy (few to few tens of MeV) is evolving rapidly. Several existing or planned large detectors world-wide will produce high-statistics signals of the next Galactic stellar collapse event (supernova or black-hole formation). The diffuse supernova neutrino background (DSNB) is coming into reach with the gadolinium enhancement of Super-Kamiokande and the JUNO scintillator detector. This topical workshop was meant to interface the communities of supernova and neutrino theorists and protagonists of the evolving experimental side. The goals were to enhance the information flow and mutual understanding between these communities and to develop a better definition of the observational targets (What can we learn?) and of the deliverables that should be provided by neutrino and SN theory as possible benchmarks for detector optimization and observation strategies (What should we do?). This topical workshop continued the discussions of previous workshop at the INT in Seattle in August 2016.

The topical workshop was focused on the following important topics:
(i) What are the perspectives to measure MeV and ultra-high-energy neutrinos from stellar explosions?, Which sources are the most promising ones, in particular for multi-messenger supernova (SN) physics?

(ii) What are the current model predictions for individual SNe, and the diffuse supernova neutrino background (DSNB).

(iii) What are the current frontiers in describing the microphysics needed for the source modeling? What are major uncertainties?

(iv) What can we learn about the core-collapse physics from a future galactic SN event?

(v) What do we know about neutrino-flavor oscillations in SNe?

(vi) What is the impact of non-standard physics scenarios on the expected neutrino signal from SNe?

(vii) What "hard" signatures of oscillations and core-collapse physics are predicted for the SN neutrino signal (i.e. features fairly independent of underlying model assumptions)?

(viii) Given the present diversity of small, medium and grandly sized SN neutrino experiments using different detection techniques: What benefit can be gained by a combined analysis of their various neutrino signals?

(ix) Which is the potential of upcoming large scale neutrino detectors such as the Hyper-Kamiokande Cherenkov detector, the JUNO scintilla-tor detector and the DUNE liquid argon detector? To what extent can the enrichment of the existing Super-Kamiokande detector with gadolinium and other novel techniques improve the SN neutrino detection?

(x) What are the most promising experimental techniques for the DSNB detection?

These major topics were covered by one to two overview talks per day and a number of shorter contributions in the afternoon sessions, preparing the ground for subsequent moderated discussion sessions. Among the main results were the formulation of a list of 13 questions that can be addressed by a possible future detection of a SN neutrino burst as well as of 10 questions associated with the interpretation of an upcoming DSNB detection. Both topics will require steadily improved theoretical studies to build reliable foundations for extracting information from the measured data.

The SNOBS participants decided to set up a Supernova Neutrino Advance Readiness Exercise (SNARE) in which the practical handling of neutrino detections shall be exercised by channeling fake signals through a detection data-processing pipeline for subsequent interpretation of the signal with respect to their physics contents. The goal is to convince as many existing and planned experiments as possible to participate and test their analysis chains on the data simulated. The exercise is seen as a first step towards a multi-experiment and multi-messenger exploration of galactic supernova signals.

Among the most relevant open problems, the following points are of very high priority: an improved conceptual understanding and a more rigorous solution of neutrino-flavor oscillations in the neutrino-dense SN environment; the exploration of consequences of non-standard neutrino physics on the source dynamics and associated neutrino-signal predictions; a better theoretical and experimental consolidation of neutrino interactions with heavy nuclei in the upcoming new detector facilities; the possible benefit of combining the findings of present (and future) neutrino observatories in deciphering the signatures of core-collapse and oscillation physics embedded in the SN neutrino signal.