Supernova Neutrino Detection at Current and Future Neutrino Detectors

Shunsaku Horiuchi (UC Irvine), with J. Beacom, E. Dwek, C. Kochanek, J. Prieto, K. Stanek, and T. Thompson (OSU)

Introduction

Core-collapse supernova (CCSN) neutrinos reveal otherwise "opaque" features of the explosion mechanism, nucleosynthesis, formation of compact objects, and many other physics. Detection is within reach of current and next generation detectors.

Diffuse supernova neutrino background (DSNB)

The DSNB has two major inputs:

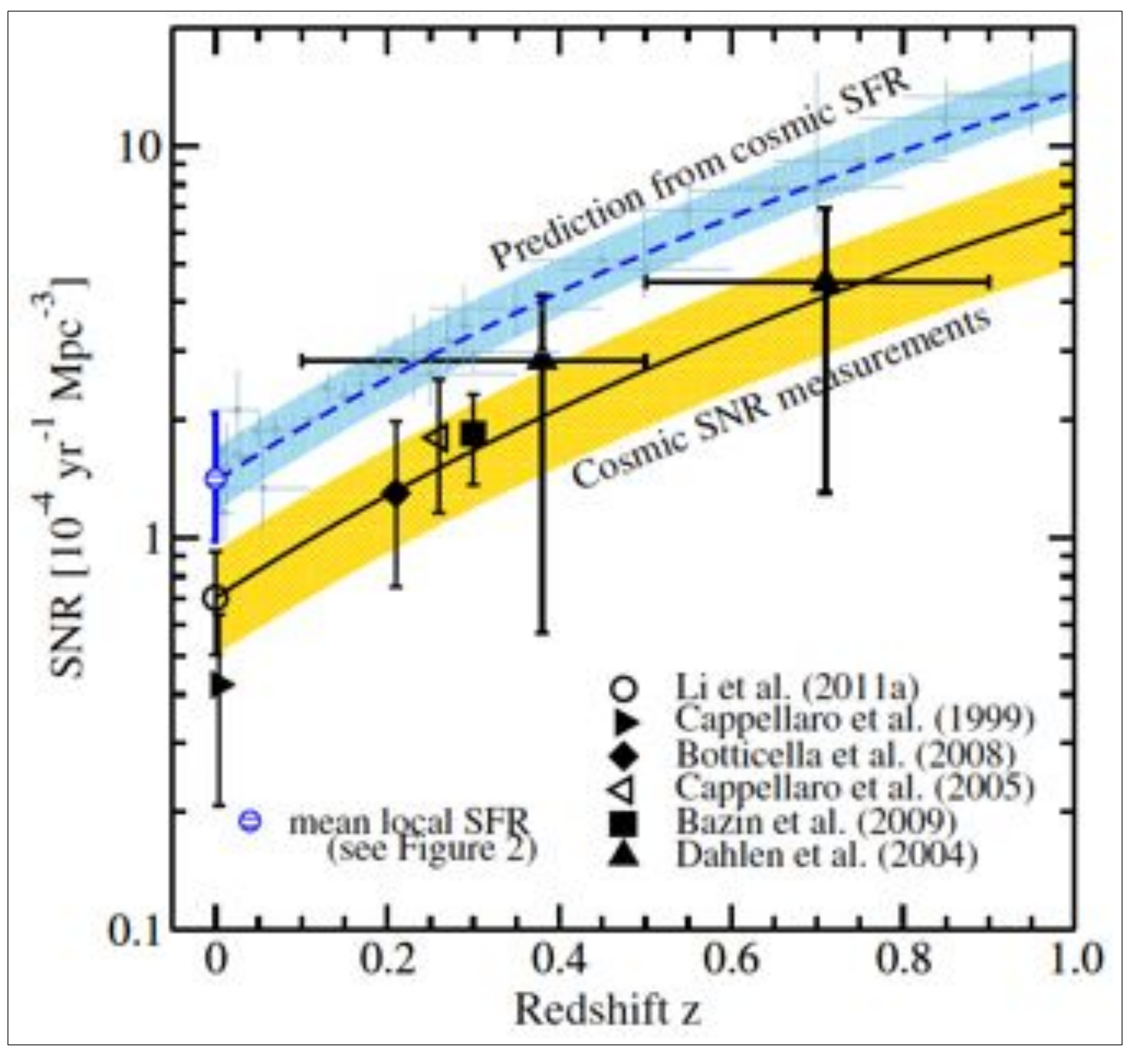
$$\frac{d\phi(E)}{dE} = c\int R_{\rm CCSN}(z)\,\frac{dN(E')}{dE'}\,(1+z)\left|\frac{dt}{dz}\right|dz$$

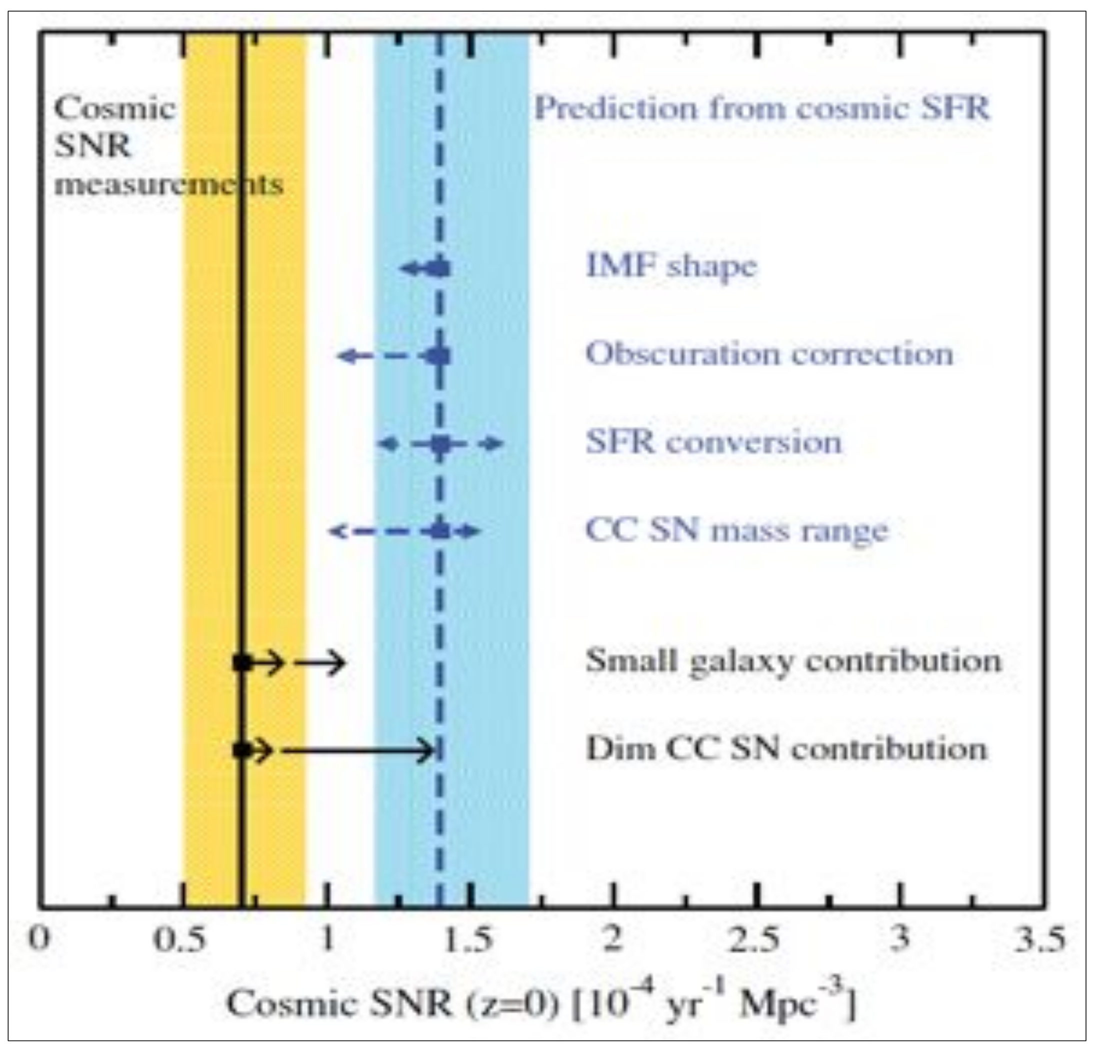
Astronomy input: the past CCSN rate history

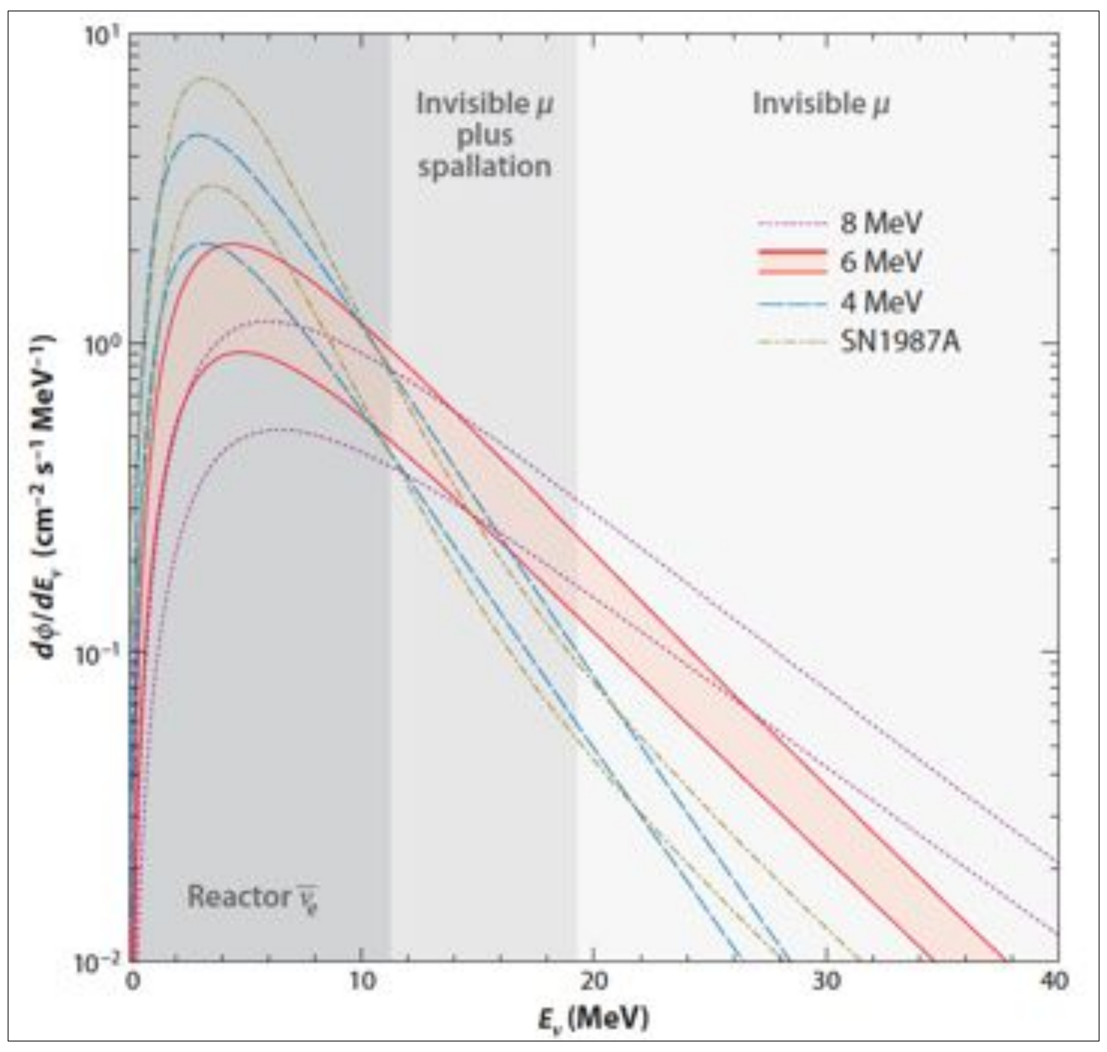
The precision of the supernova rate, R_{CCSN}, is ~30% and improving. The star-formation rate is known more precisely, to ~25%. However, the direct CCSN rate measurements (yellow) fall short of those predicted from the star-formation rate (blue). This is likely due to many dim supernovae being missed at cosmic distances (*Horiuchi et al. 2011*).

Astrophysics input: the neutrino emission per CCSN

Predictions are derived from numerical simulations and considerations of neutrino flavor mixing (vacuum, matter, and collective effects). The nuebar ranges from T_ν~ 4–5 MeV. Collective effects affect the diffuse flux at the 5-10% level, MSW by ~50%. SN1987A provides one benchmark.







The astronomical uncertainties are small and decreasing, and DSNB detection will tell us about the neutrino spectrum. Only the DSNB provides a test of neutrino emission from *all* types of CCSN.

DSNB is a *guaranteed* signal. Detection rates at Super-Kamiokande (SK) are shown in the table, for current SK and Gd doped SK.

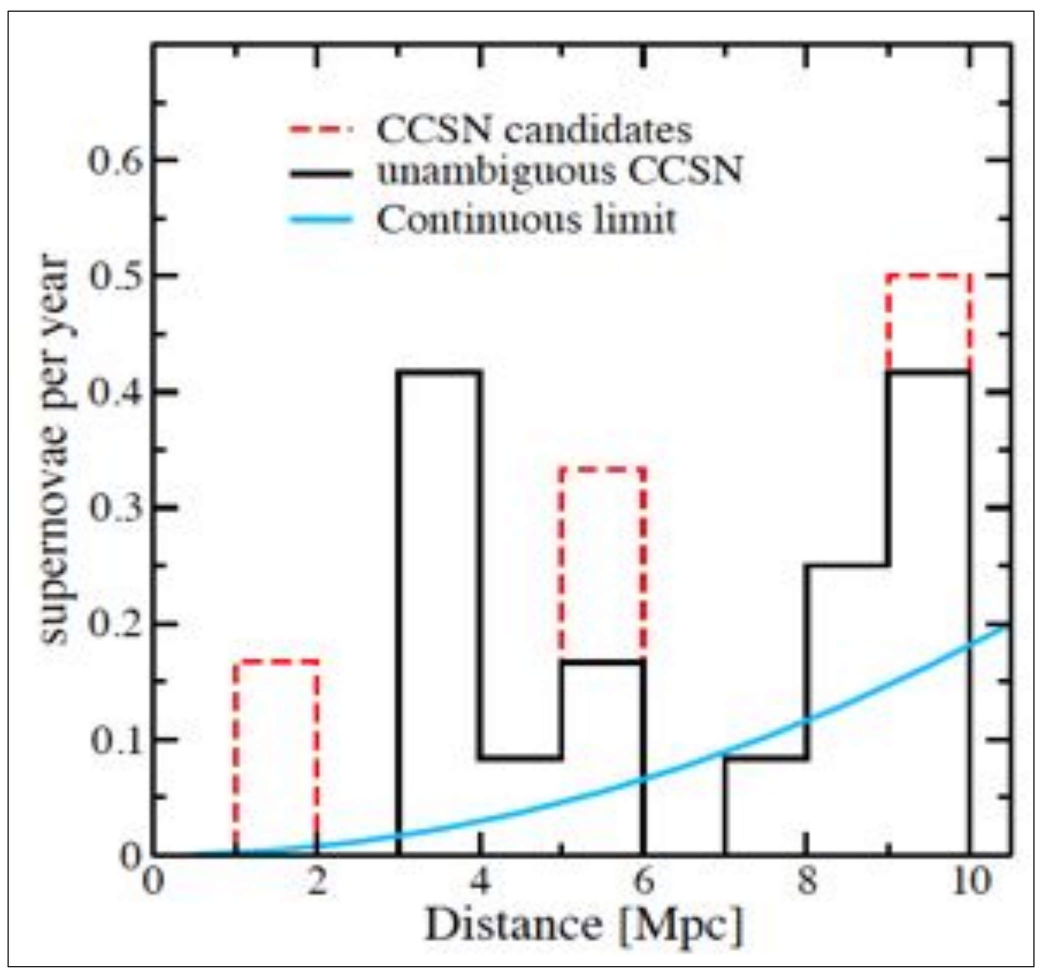
	SK (22.5 kton)	SK with Gd (low threshold)
6 MeV	1.3 +/- 0.4	3.5 +/- 1.1
4 MeV	0.4 +/- 0.1	1.8 +/- 0.5
SN 1987A	0.5 +/- 0.1	1.7 +/- 0.5

Miniburst neutrinos

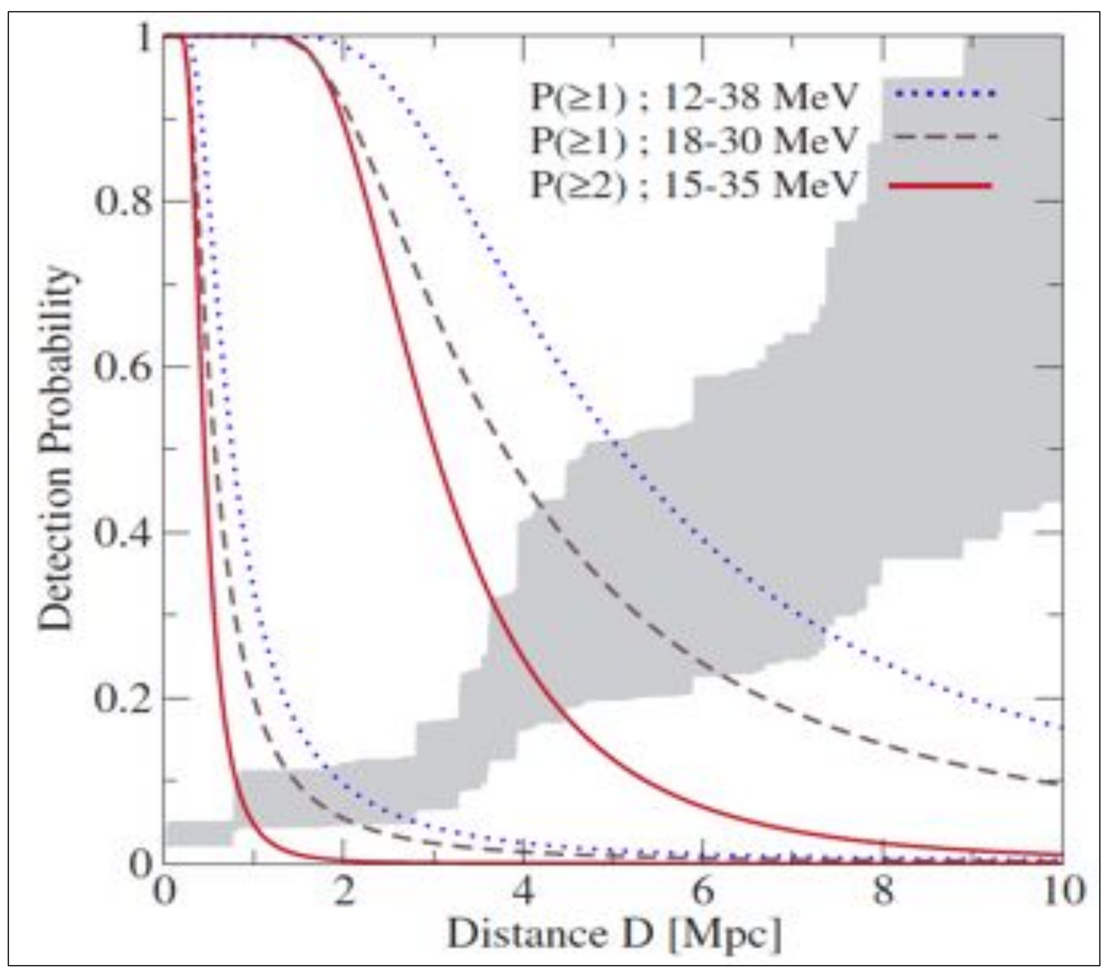
Nearby supernovae are frequent enough for a ~1 Mton water Cerenkov detector to detect supernovae almost annually.

In addition, many nearby transients show properties of both supernovae and stellar outbursts [*Thompson et al 2009*]. Dubbed "impostors," their true nature can be reliably tested by the detection of even *a few* coincident neutrinos.

Detection requires ~Mton water Cerenkov detectors, like Hyper-K, preferably with low threshold, ~12 MeV.



Supernova rate, "impostors" in red



Detection probabilities (*Ando et al. 2005*)

Discussions

Present: Super-K is very close to detecting diffuse supernova neutrinos. Building up several years worth of data will tell us about the average neutrino emission per supernova.

Future: must go beyond Super-Kamiokande

Very large water

Just like Super-K: no new backgrounds, could use Gd for improvement. e.g., Hyper-K with > 10 times rate of Super-K

Large liquid Argon

Nue sensitivity, good event ID, and no invisible muons, but new backgrounds? e.g., GLACIER with ~4 times rate of Super-K

Large liquid scintillator

Oil based, it has neutron tagging, no invisible muons, but new NC backgrounds. e.g., LENA with x2 rate of SK