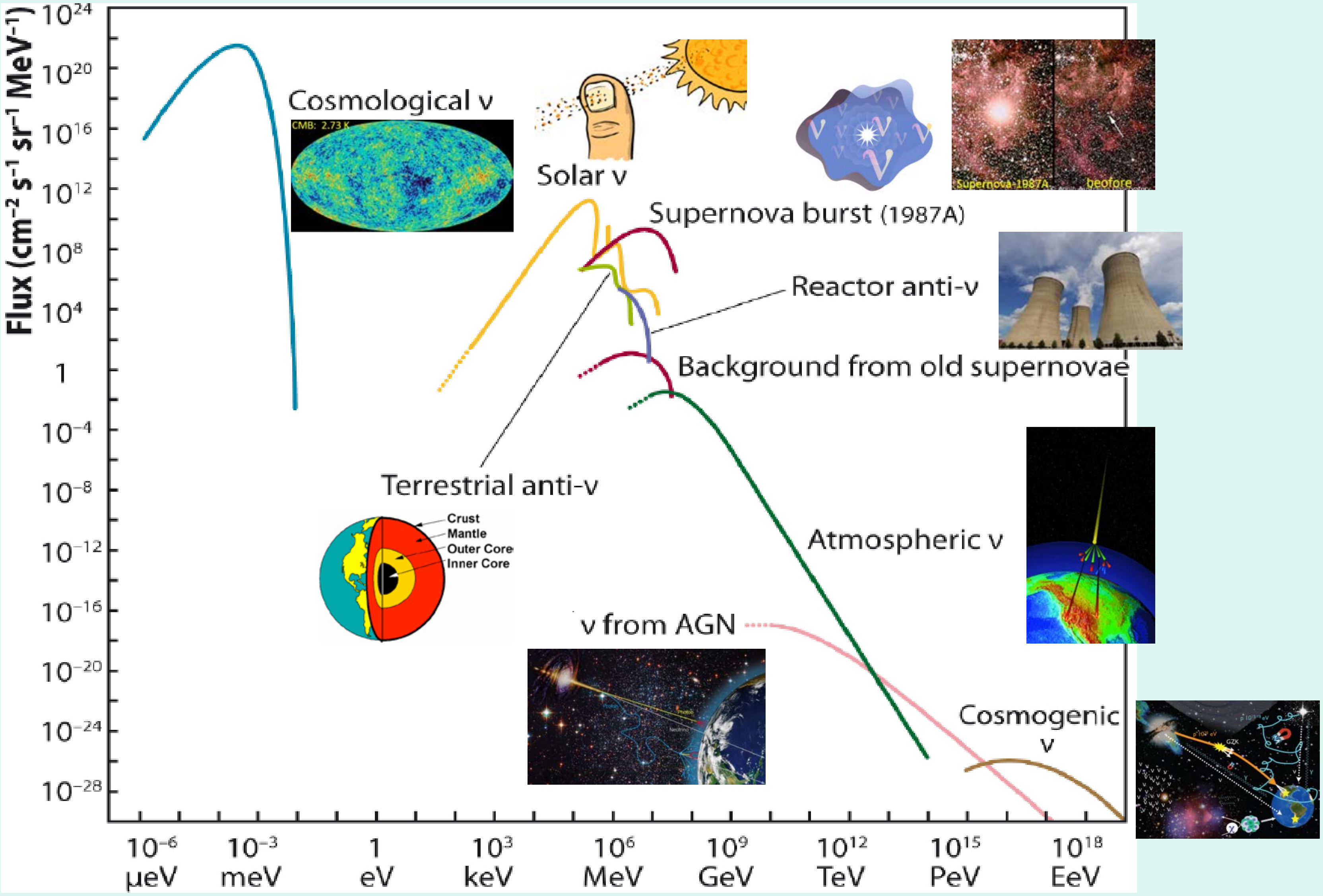
Future initiatives in Neutrino and Multimessenger Physics

XVII International Workshop on Neutrino Telescopes
March 17. 2017
Soo-Bong Kim

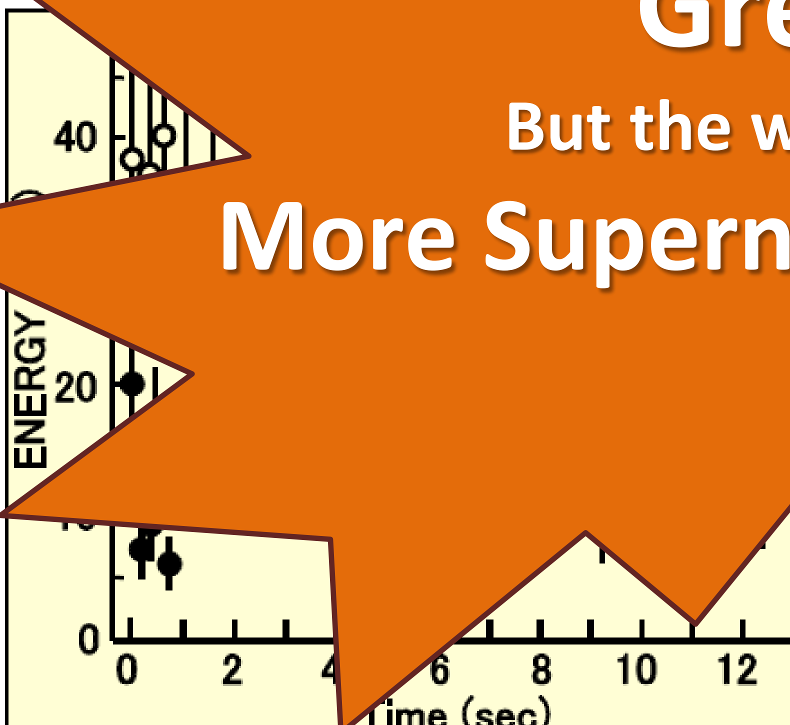
Neutrino Science

- **Particle physics**: neutrino mixing, mass, … using cosmic (solar/atmospheric/supernova), accelerator, reactor and source neutrinos
- **Astronomy**: neutrinos from the Sun, supernova, AGN, BH-BH collision, …..
- **Cosmology**: Evolution and structure formation with cosmological neutrinos. Associated with CMB.
- **Application**: Geoscience (heat production and tomography of earth cores), Nuclear proliferation, ….

Neutrino Sources



SN1987A at La... M... lanic Cloud



Great!

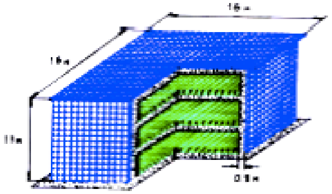
But the world needs

More Supernova Neutrinos

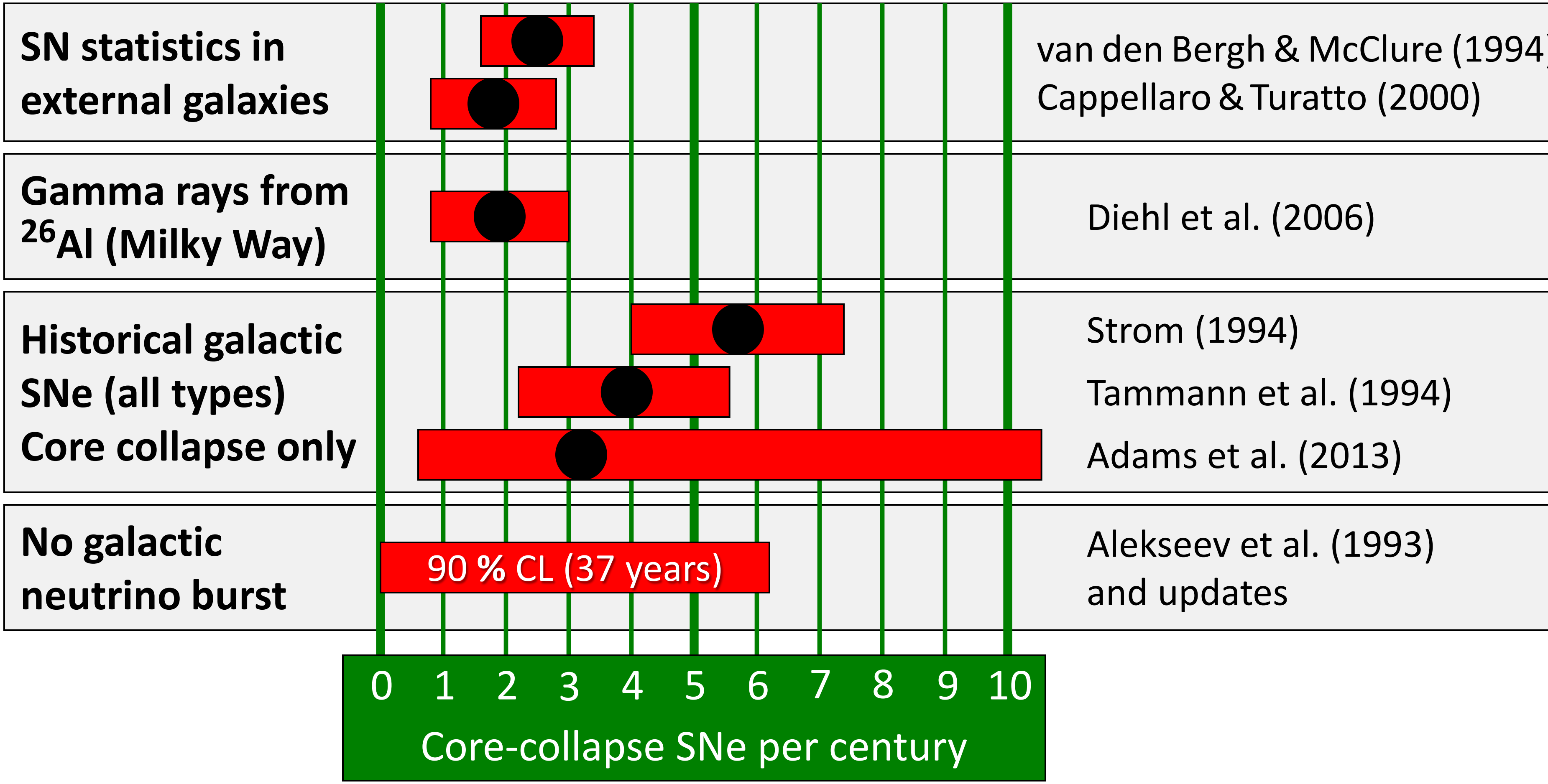
(8kton)

Liq...d Scintillator

Baksan

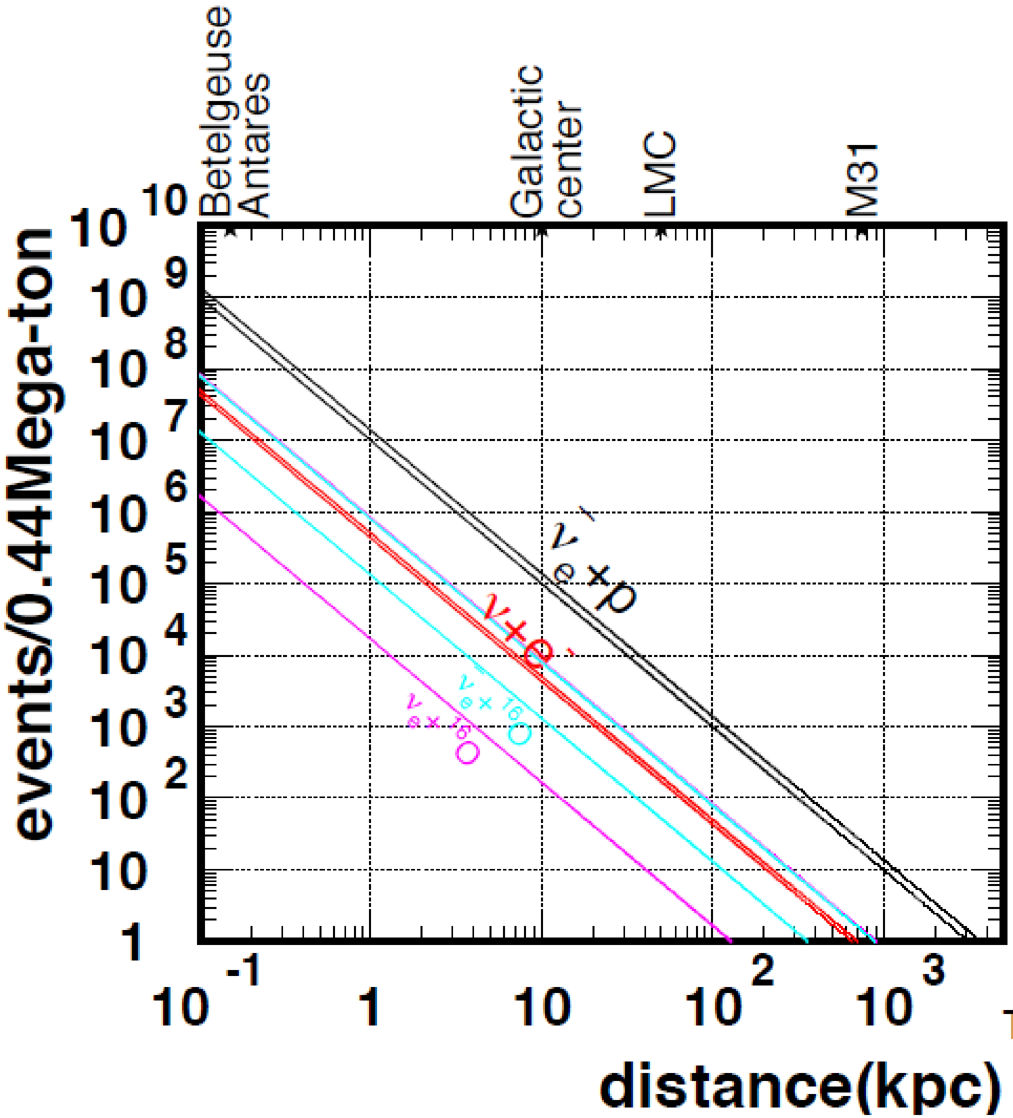


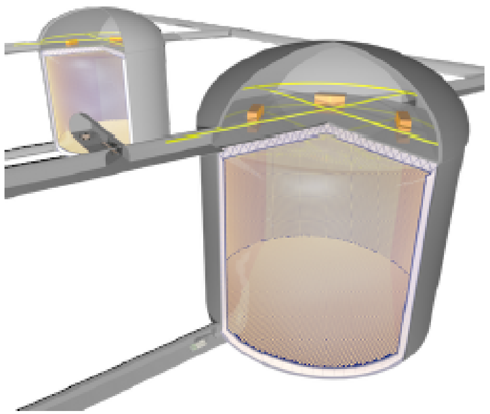
Core-Collapse SN Rate in the Milky Way



van den Bergh & McClure, ApJ 425 (1994) 205. Cappellaro & Turatto, astro-ph/0012455.
Diehl et al., Nature 439 (2006) 45. Strom, A&A 288 (1994) L1.
Tammann et al., ApJ 92 (1994) 487. Adams et al., ApJ 778 (2013) 164.
Alekseev et al., JETP 77 (1993) 339.

SN burst observation by HK





Expected number of event

98k~136k ev (IBD)
4.2k~5k ev (νe ES)
(12~80 for neutronization)
160~8200 ev (ν_e CC)
1300~7800 ev ($\bar{\nu}_e$ CC)

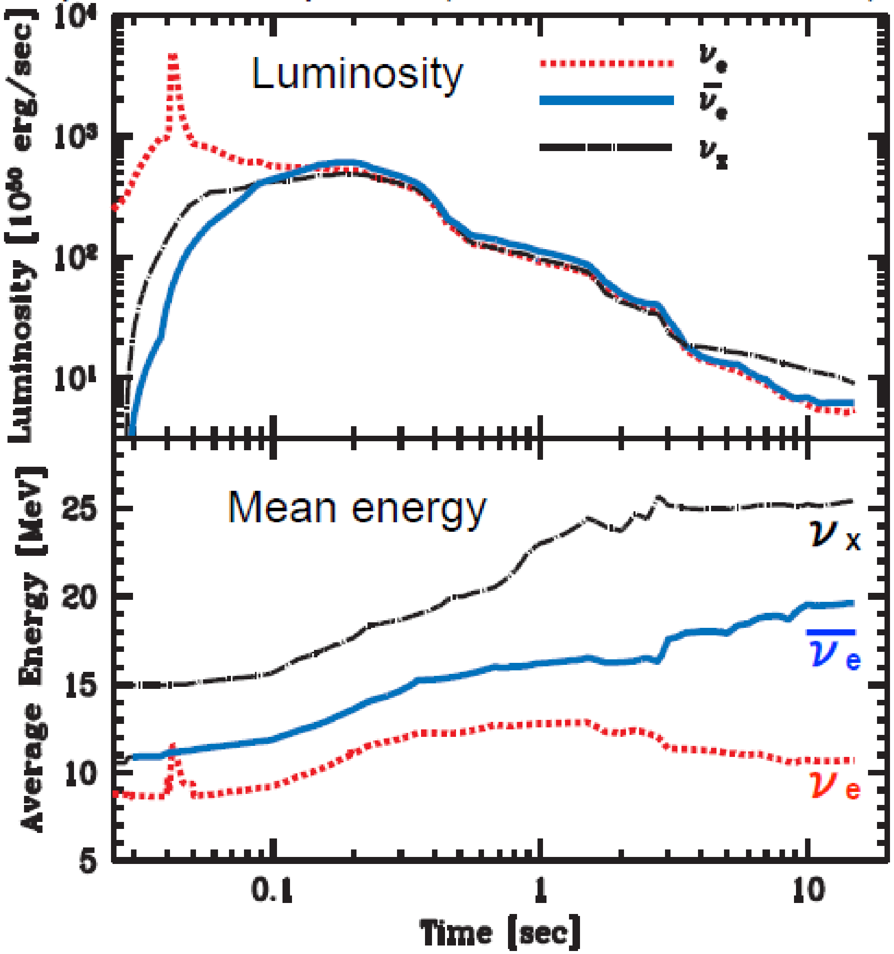
at 10kpc

Livermore simulation

Totani, Sato, Dalhed, Wilson, ApJ. 496 (1998) 216

Physics motivation

Expected time profile (Livermore simulation)



Totani, Sato, Dalhed, Wilson, ApJ. 496 (1998) 216

What we can learn

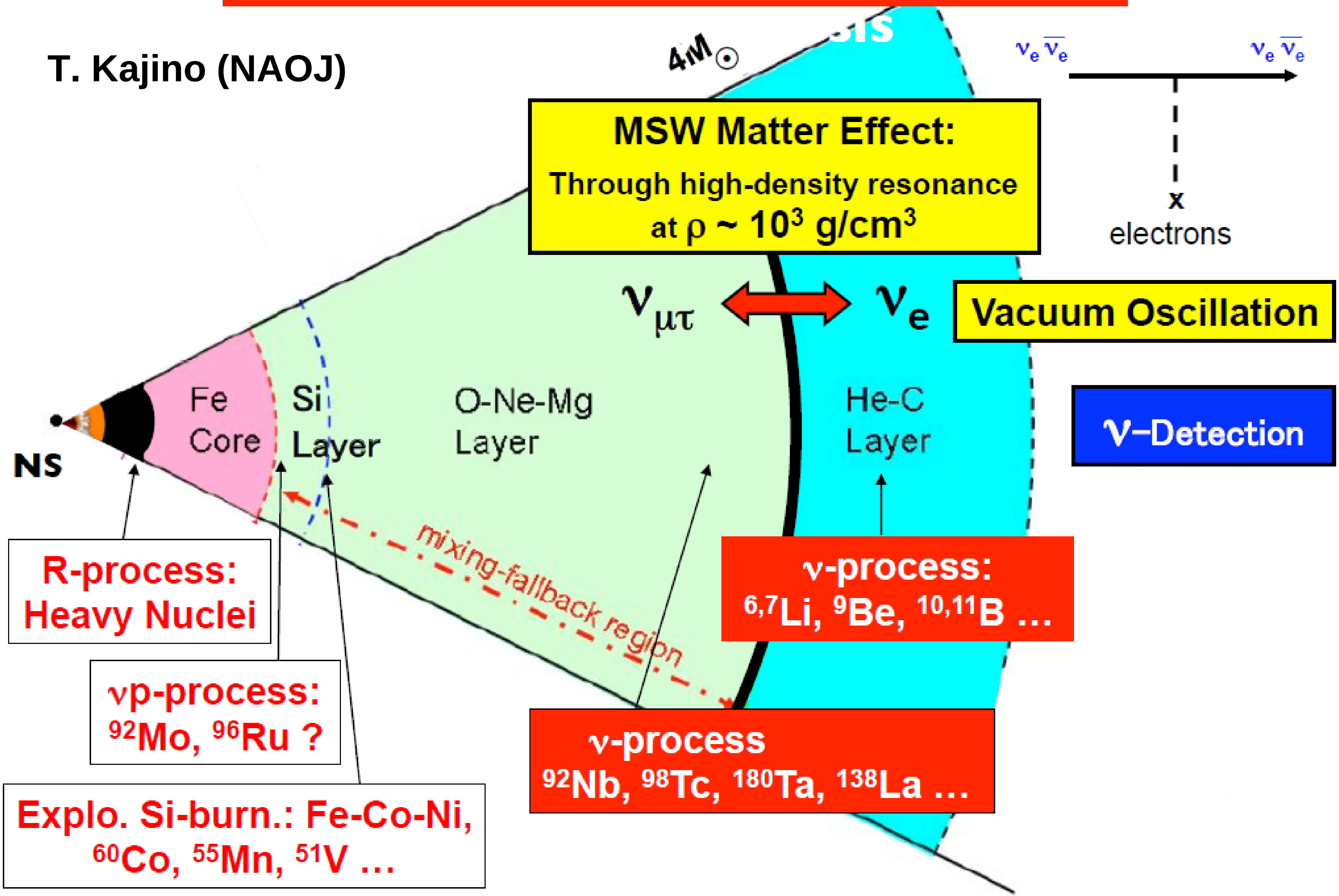
✓ Core collapse physics
- explosion mechanism
- proto-neutron star cooling
- black hole formation
- etc..

✓ Neutrino physics
- neutrino oscillation
- etc..

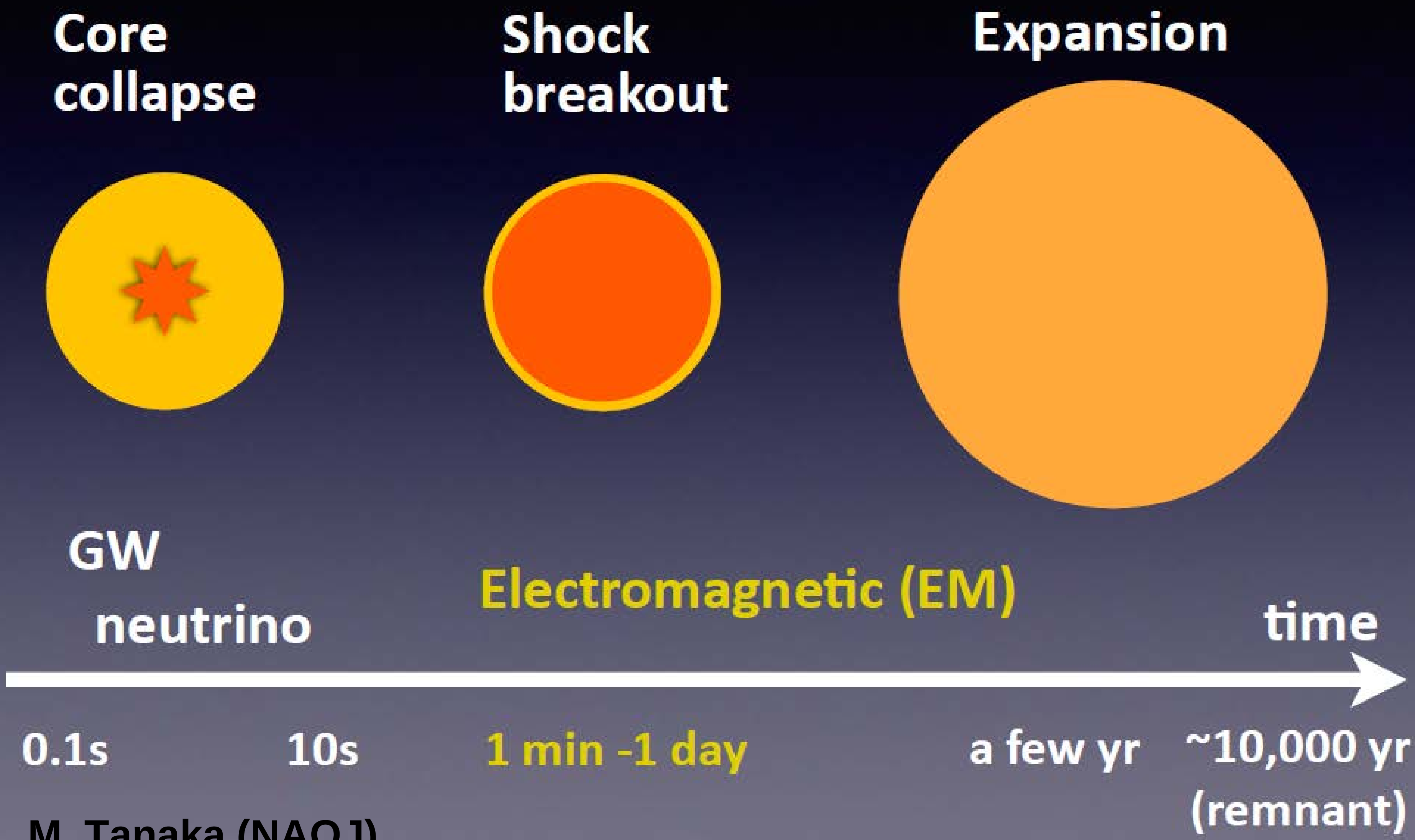
Measurements of neutrino
flavor, energy, time profile
are the key points

ν-Oscillation and

T. Kajino (NAOJ)

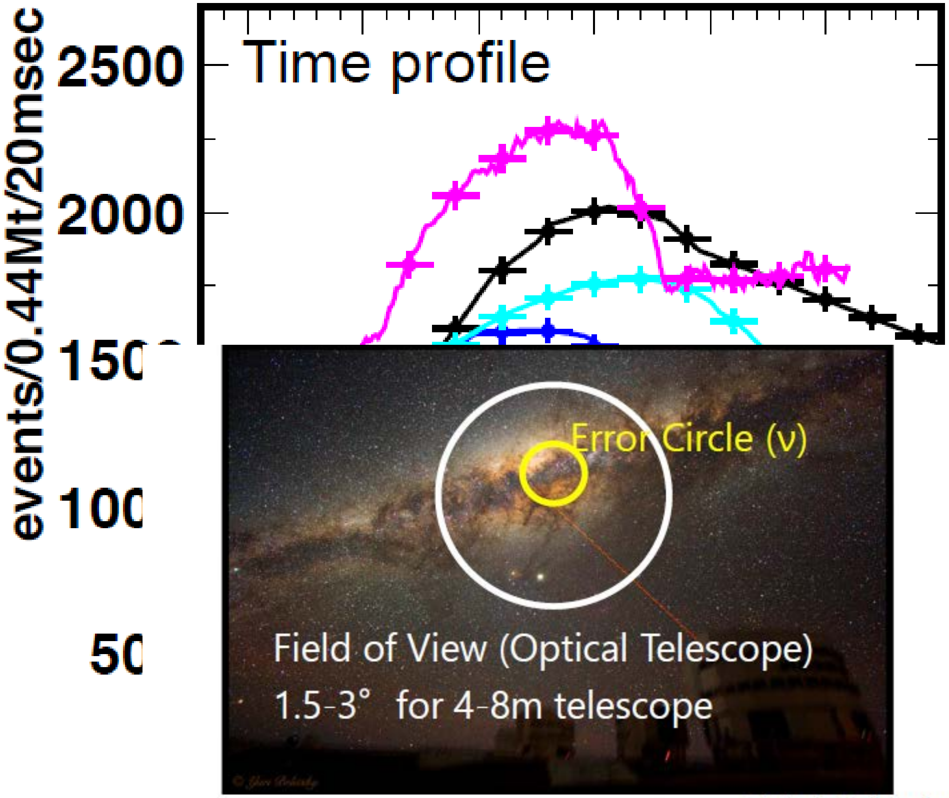


Timescales of core-collapse supernova



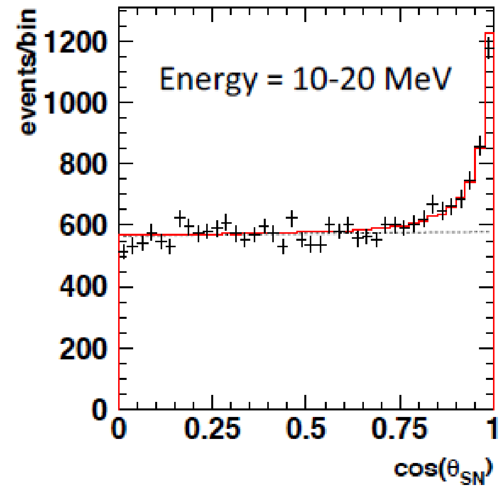
M. Tanaka (NAOJ)

SN burst observation by HK



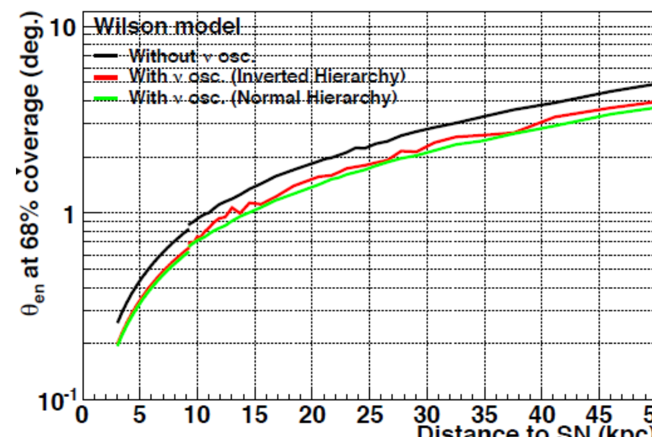
©Yuri Beletsky

	SK	SK-Gd	HK	HK-Gd
Error Circle	6°	3°	1.4°	0.6°



SN directionality

Elastic scattering can measure the direction of Supernova



~1 degree at 10kpc

More accurate than most of the optical telescope

What electromagnetic (EM) signals tell us

M. Tanaka (NAOJ)

- **Global properties of SN**

  Expansion velocity, ejected mass, and kinetic energy

  Doppler velocity, direct imaging   Timescale of light curve

- **Nucleosynthesis**

  Production of 56Ni, and other elements

  Bolometric luminosity   Spectra (absorption/emission lines)

- **Type of progenitor star**

  Composition and radius   Image of progenitor star

- **Explosion geometry**

  Distribution of chemical elements   Direct imaging, Doppler tomography, polarization, …

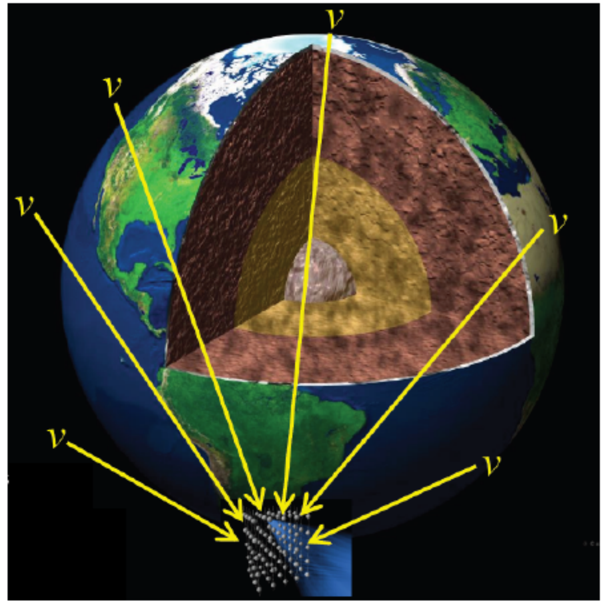
Complementary with neutrino and GWs

Synergetic observing strategies

=> full use of multi-messenger signals

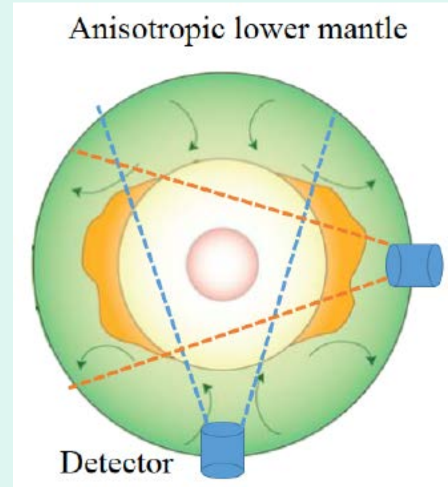
Neutrino Geophysics

- The Earth **matter density** profile can be determined from **seismic measurements**
- Matter induced **neutrino oscillation** effects however dependent on the **electron density**
- Given a matter density profile the "average" composition (or Z/A) along the neutrino path can be determined using neutrino signals (Oscillation tomography)

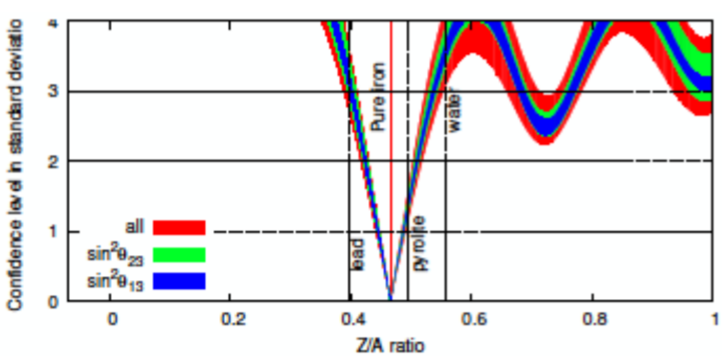


Electron density in core
Y_c=electron/nucleons

corresponding zenith angles for boundaries
inner core $\theta_\nu < 169°$ ($\cos\theta_\nu < -0.98$)
outer core $\theta_\nu < 147°$ ($\cos\theta_\nu < -0.84$)

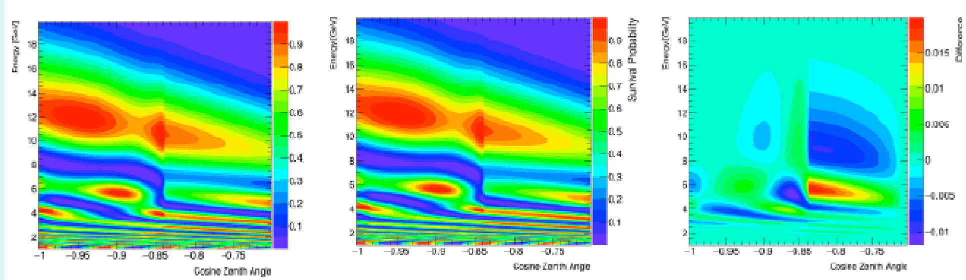


- Hyper-K will be the first experiment that can experimentally confirm a iron like core.



Muon neutrino survival probability

Z/A=0.4957 Z/A=0.5007 Difference



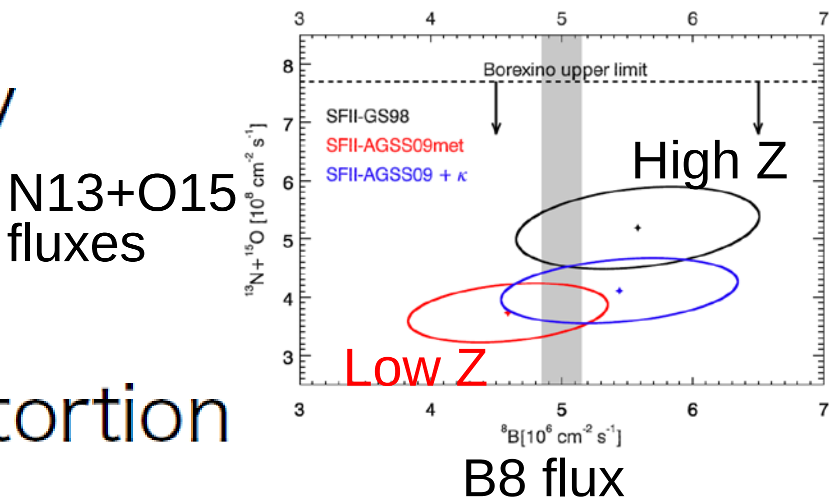
- Tomography with multiple detectors

Solar neutrino measurement in HK

(1) Matter oscillations

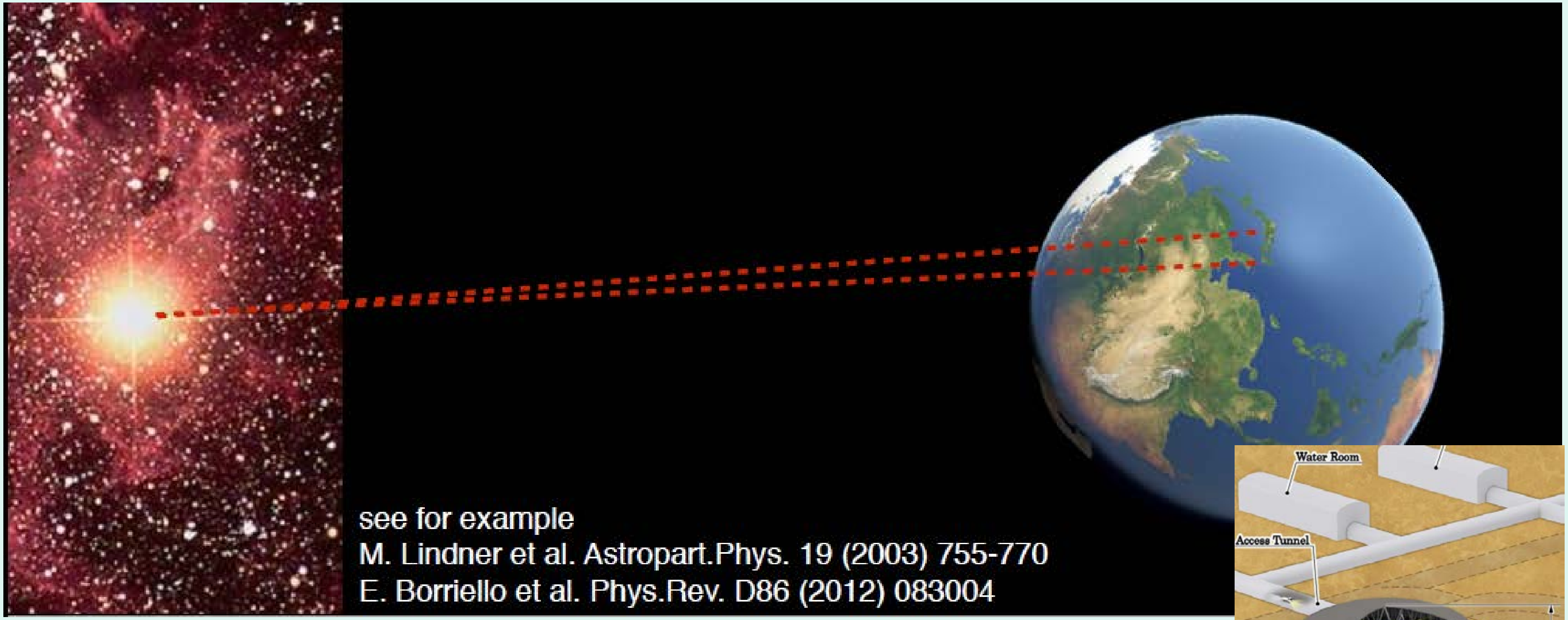
(2) CNO cycle neutrinos (±10%) → Metallicity problem of the Sun (Z/X)

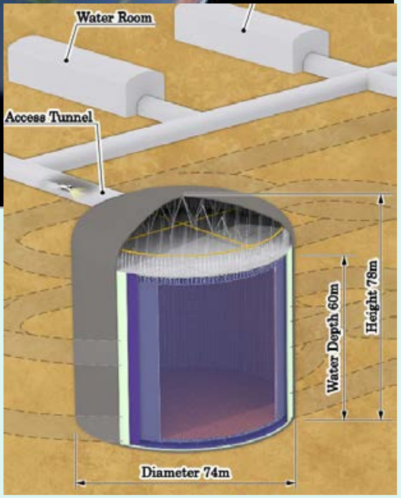
- Flux measurement with large statistics
- Day-Night asymmetry
- Seasonal variation
- Energy spectrum distortion
- Hep neutrino observation



* Accurate solar neutrino flux measurements together with CNO neutrinos will solve a main problem of nuclear astrophysics.

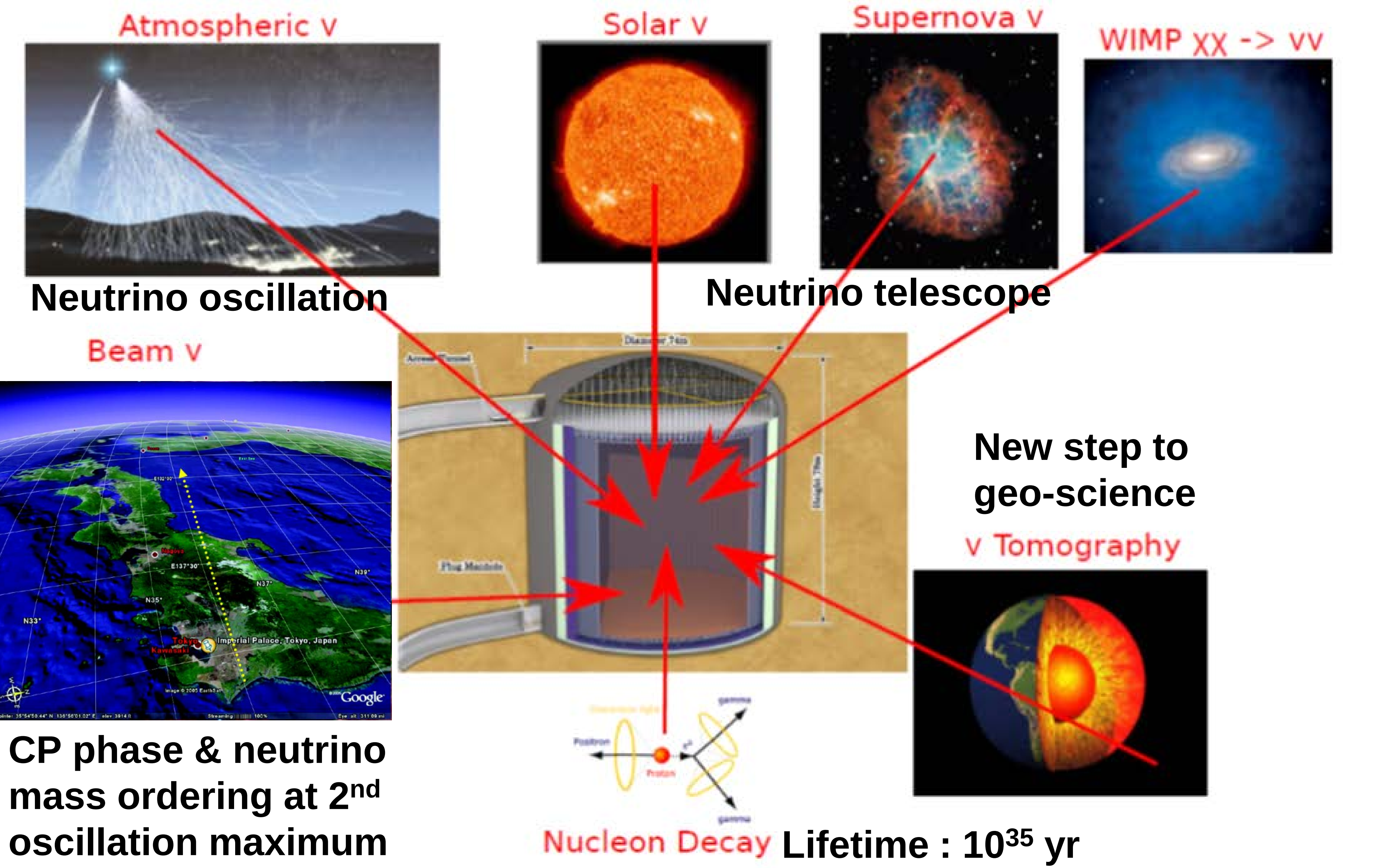
Astronomy Potentials with Korean Neutrino Detector and Telescope



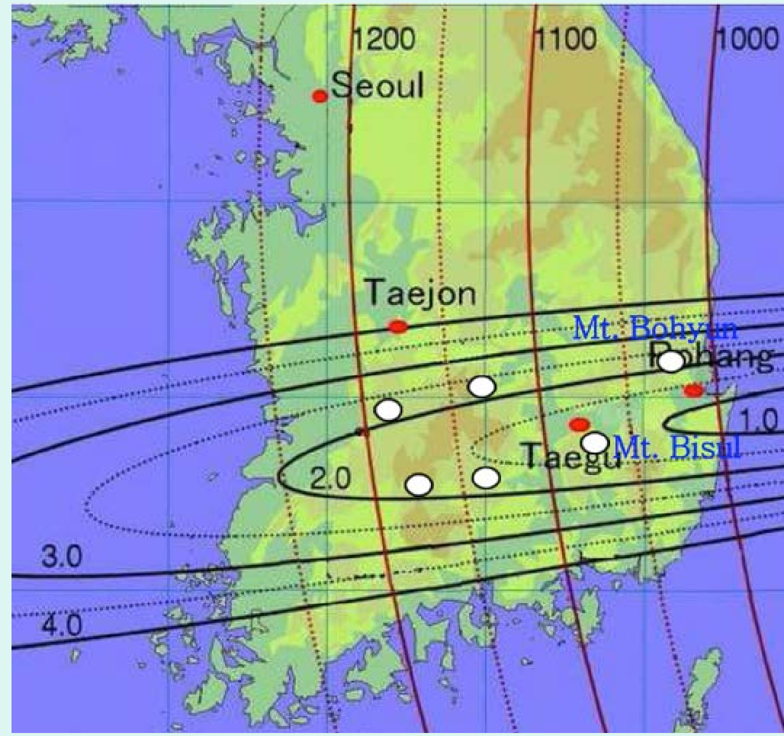


KNO (Korean Neutrino Observatory)

A Large Water Cherenkov Detector in Korea



Korean Neutrino Observatory (KNO)



Mt. Bisul