Study for g-mode oscillations in the Sun using solar neutrino with Super-Kamiokande

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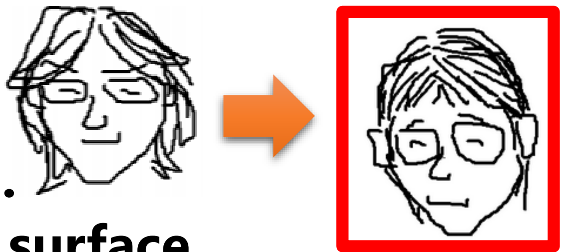
for the Super-Kamiokande collaboration



■ Introduction and motivation

- There are several periodic variations in the Sun.
  - (1) 11-years periodic change of sunspot at the surface.
  - (2) Solar oscillations around its equilibrium due to restoring force.

Oscillation	Restoring force	Region	Frequency
p-mode	Pressure	Surface convection	A few mHz (~ 5 minutes)
g-mode (Never detected)	Gravity (Buoyancy)	Core	100-300 μHz (a few hours)

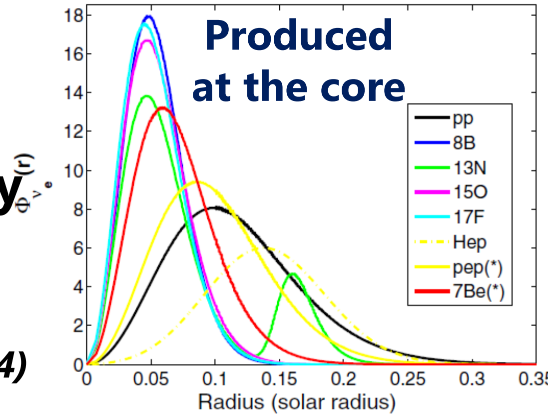
- These variations may affect the solar neutrino production.

→ Search for periodic variation using solar neutrino in Super-Kamiokande.

■ ^{8}B neutrino production and g-mode oscillation

- Production rate of ^{8}B ν is depends on temperature.
  → $T^{24\text{-}25}$ (T_{core}~$10^{6\text{-}7}$ K) at the core of the Sun.

Astrophys. J. 765, 14 (2013)



- Due to g-mode, temperature (electron density) may fluctuate at the core of the Sun.

→ **Flux of ^{8}B ν may be amplified by a factor of 170.**

Astrophys. J. Lett. 792, L53 (2014)

■ Method to search for g-mode oscillation

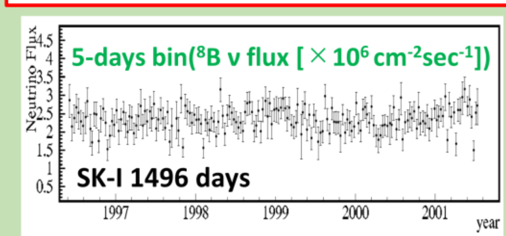
- Super-Kamiokande has accumulated **~100k neutrino events** so far.
- There are **two methods** to search for g-mode oscillations in Super-K.

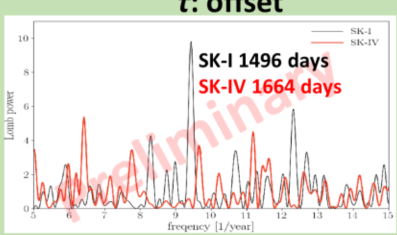
Generalized Lomb-Scargle method (Binned analysis)

Search for periodic signals in uncontinuous data set

$$\hat{p}(\omega) = \frac{1}{\sum_i y_i^2}\left\{\frac{[\sum_i y_i \cos\omega(t_i-\hat{\tau})]^2}{\sum_i \cos^2\omega(t_i-\hat{\tau})} + \frac{[\sum_i y_i \sin\omega(t_i-\hat{\tau})]^2}{\sum_i \sin^2\omega(t_i-\hat{\tau})}\right\}$$

y_i: flux of i-th bin
t_i: time of i-th bin
ω: angular frequency
τ: offset



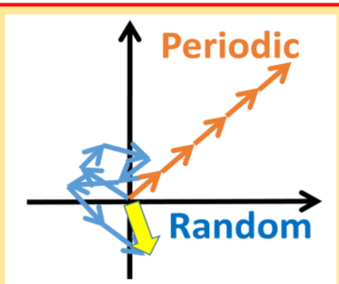


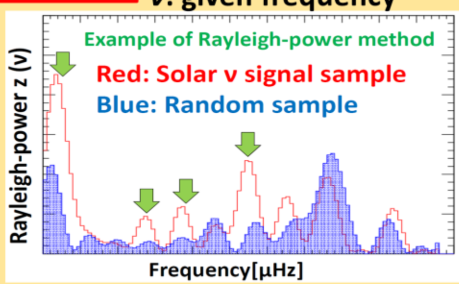
Rayleigh power method (Unbinned analysis)

Power spectrum considering timing of observed events

$$z(\nu) = \frac{1}{N} \times \left[\left(\sum_i^N \sin 2\pi\nu t_i\right)^2 + \left(\sum_i^N \cos 2\pi\nu t_i\right)^2\right]$$

N: number of total event
t_i: time of i-th event
ν: given frequency





- For more detail: come to my poster. I'm happy to discuss this study with you.