1. Introduction

- Standard Solar Model (SSM) [1].
  - The SSM has been constructed by inputting several observation results assuming:
    (1) Spherically symmetric,
    (2) Hydrostatic equilibrium with no macroscopic motion except for the convection,
    (3) No mass loss, no mass accretion, no rotation and no magnetic field.
  - The model well predicts the production and energy spectrum of solar neutrinos.
- Periodic variations in the Sun.
  - 11-years periodic change of the sunspot at the surface. This leads to the change of the magnetic field.
  → Some mechanisms propose conversions of neutrino ($\nu_e \rightarrow \nu_R$) if neutrino has a large magnetic moment [3-5].
  - Solar oscillations around its equilibrium state because of the Sun’s restoring force [6].
  → Acoustic oscillation (p-mode) due to compressibility [7-9] or gravity oscillation (g-mode) due to buoyancy [10].

2. G-mode oscillation and neutrino

- Introduction about g-mode oscillations [11, 12].
  - G-mode oscillations are described as spherical harmonics function.
  - They may affect both electron density and temperature in the core of the Sun.
- These modes have not been detected because their amplitudes are low at the surface.
- Typical frequencies are about a few hours (~100-300 μHz) [11].
- $^8$B neutrino production rate.
  - G-modes are trapped under the convective zone, where $^8$B solar neutrino is produced.
  - Production rate depends on temperature. It is proportional to $T^{24-25}$ ($T = 10^6 K$) [13].
  → Its production rate is amplified by a factor of 170 [14].
  → It may affect the propagation of solar $\nu$, MSW effect [15, 16], thus survival probability of $\nu_e$ [12].

3. Super-Kamiokande & Methods

- Super-Kamiokande [17] and solar neutrino observation [18-21].
  - Cherenkov light produced via $\nu - e$ elastic scattering.
  → Recoil electrons preserve the direction of incident neutrinos.
- Two methods to search for periodical signals.
  - Generalized Lomb-Scargle method (Binned analysis)
    Search for periodic signals in uncontinuous data set [22-24].
    - $\nu$: flux of i-th bin
    - $t$: time of i-th bin
    - $\omega$: angular frequency
    - $\phi$: offset
    - 5-days bin ($8 \nu$ flux [$10^6 \text{cm}^2 \text{sec}^{-1}$])
    
  - Rayleigh power method (Unbinned analysis)
    Power spectrum considering timing of observed events [26, 27].
    - $N$: number of total event
    - $t$: time of i-th event
    - $v$: given frequency
  - Cover 2 cycles of solar activity

4. Progress, Future prospect and Summary

- Progress and future prospects
  - Dead-time due to calibrations affects the sensitivity in Rayleigh power method.
  - We have started to develop a randomly timed MC simulation considering operation-time/dead-time of SK.
  - We will open the data soon after the MC production and compare with the former results from SNO collaboration [28-30].
- Summary
  - The SSM has been constructed for 50 years. However, the Sun oscillates around its equilibrium such as p-mode or g-mode.
  - G-mode oscillation may amplify the solar $\nu$ production rate by a factor of 170 because of fluctuation of electron density.
  - SK has a chance to search for g-mode oscillations by using its timing information of the observed solar $\nu$. 