1. Super-Kamiokande

- 50 ktons water, 22.5 kton fiducial volume
- Instrumented with 11129 20 inch PMTs
- Detects Cherenkov light from charged particles passing through water
- Already hugely successful in proton decay searches and neutrino detection
- Soon to be upgraded for next phase with Gadolinium doping
- By adding 0.2% Gd salt by mass, will detect up to 80% of neutrons [1].

2. Thermal Neutron Capture on Gadolinium

- Isotopes of Gadolinium have some of the highest cross sections for thermal neutron capture [1].
- Neutron capture followed by gamma ray cascade of around 8 MeV within 20 microseconds; enough energy to be reliably detected in Super-K.
- Neutron capture gammas are studied using MC
- Background is modelled using real data taken in SK

3. Pre-Supernova Silicon Burning Neutrinos

- Extra early supernova warning for nearby stars - before the usual supernova neutrino signal
- Never before seen astrophysical object, not visible to EM astronomy!

- Massive star prior to core collapse
- Star running out of H and He
- Contracts and gets hotter
- Heavier nuclei are fused

- Rapid increase to production of neutrinos and antineutrinos [2]
- At SK-Gd, detection efficiency for antineutrinos will be increased by neutron detection

- Detects 1000s of events in a day at SK-Gd for stars at<1kpc
- Mean energy ~2 MeV

4. Backgrounds

- Low energy backgrounds at SK are intrinsic radioactivity and cosmic muon spallation products
- Look for neutron capture candidates in coincidence with very low energy positron candidates

- Main background may be reactor neutrinos – will depend on Japanese nuclear reactors

5. How much warning and range?

- Depends on mass of star, and the mass hierarchy!
- Some uncertainty in intrinsic background and Japanese reactor situation
- Max warning for Betelgeuse is ~60 hours (1 per 2 year type-II error rate assumed)
- Max range for 3σ discovery ~900 parsecs
- There are 41 red super giants in this range

6. Summary and Conclusion

- The next stage of Super-Kamiokande is doping with gadolinium for efficient neutron tagging
- A supernova is often preceded by silicon burning
- Silicon burning rapidly increases the electron antineutrino luminosity and average energy – can be detected by SK-Gd
- Main backgrounds are intrinsic radioactivity and reactor neutrinos
- SK-Gd would detect this for a star up to 900 parsecs away
- Up to 60 hours early warning before Betelgeuse goes supernova

References


\[ \bar{\nu}_e \rightarrow \bar{\nu}_e \text{ in 0.2% Gd salt} \]

\[ \text{Some candidates} \]

\[ \text{Alarm would watch for an increase in the rate of candidate events} \]

\[ \text{Likelihood threshold set by type-II error rate: is 1 false alarm per month OK? 1 per year? 1 per 10 years?} \]