

Large Dark Matter and Neutrino Experiments

An Intimate Connection

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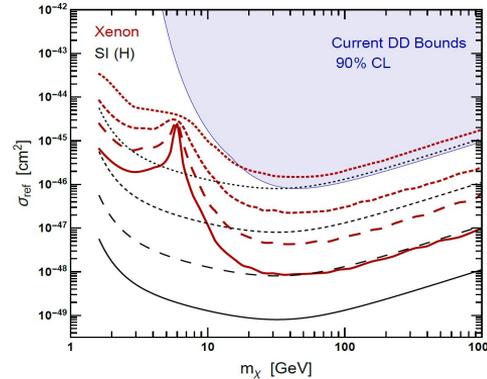
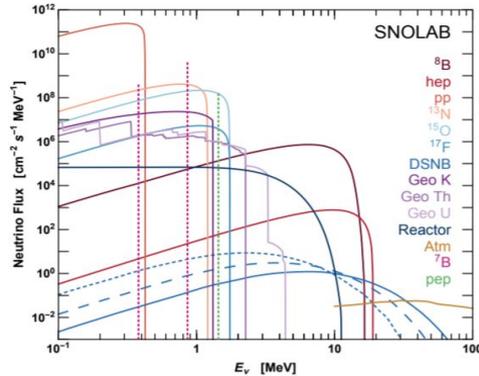
The Era of Large Underground Experiments

- Exploration of neutrino physics and direct DM detection led by large experiments (Super-Kamiokande, Xenon1T ...)
- Further advances call upon even larger experiments
 - neutrino physics (δ_{cp} , mass hierarchy) → Hyper-K, DUNE
 - direct DM detection (probe WIMPs deeper) → DARWIN, Argo ...

Dark Matter Experiments as Neutrino Telescopes

DM-Neutrino Telescopes

- Direct detection probing further will encounter irreducible ν -background: **“neutrino floor”**
(Strigari, Dutta, others)



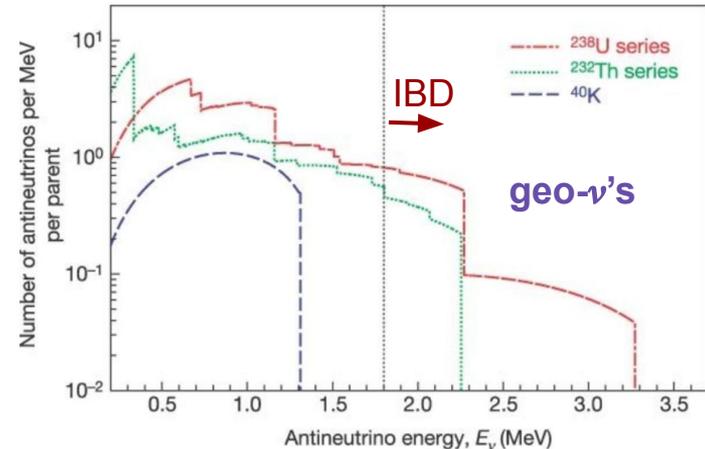
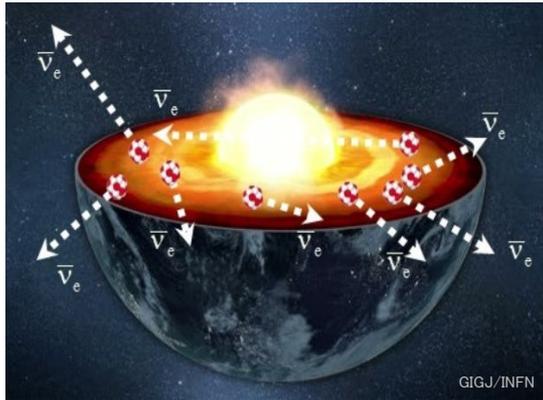
[Gelmini, VT, Witte, JCAP, 2018]

- Curse for DM searches, but opportunity for neutrino physics !
→ large DM experiments as **“effective neutrino telescopes”**
- With CEvNS DM experiments overcome IBD kinematic threshold, sensitivity to all flavors

***** exciting potential role of ν 's in XENON1T signals**

Example 1: Exploring Earth Formation with Geo- ν 's

- Earth emits heat, is origin primordial (Earth's formation) or radiogenic (nuclear reactions)?
→ can test with (geo-) ν 's from nuclear reactions inside Earth (first detection by KamLAND, 2005)

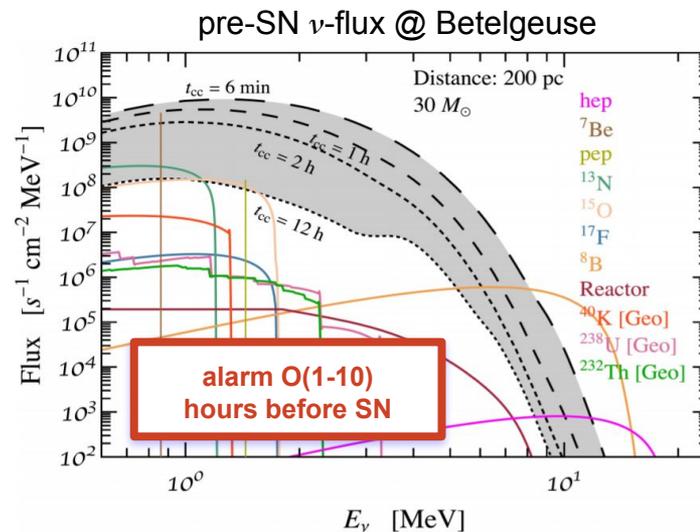
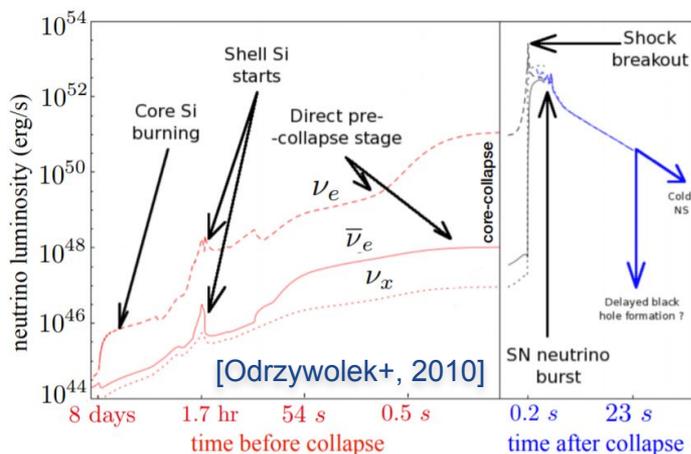


- ^{40}K geo- ν invisible for IBD → but possible in large DM detectors via CEvNS!

[Gelmini, VT, Witte, PRD, 2018]

Example 2: Supernova Forecast with pre-SN ν 's

- Galactic SN widely anticipated, but when?
 → pre-SN ν 's can provide “alarm” (already used in KamLAND, also Super-K-Gd)

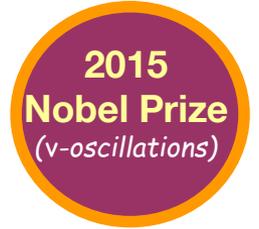


- Large DM detectors sensitive to all ν flavors, no oscillation effects

[Raj, VT, Witte, PRD, 2019]

The Dark Side of Neutrino Observatories

State-of-the-Art: Super-Kamiokande



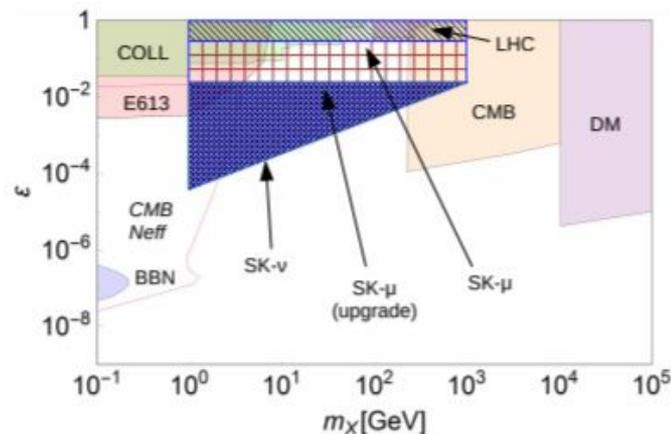
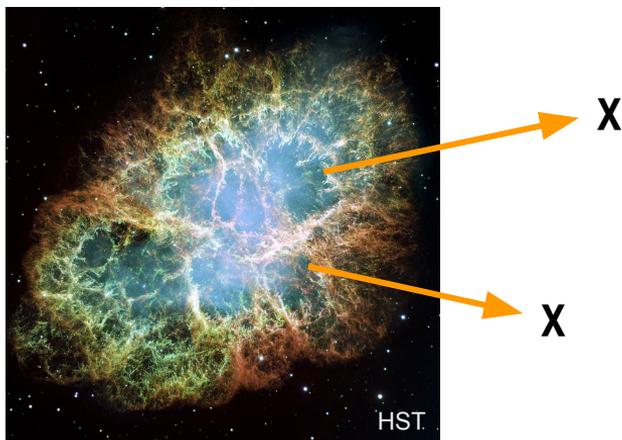
- Large (50 kt) water Cherenkov experiment (Japan), 1 km overburden
- Amazing for many neutrino topics
 - atmospheric- ν , supernova- ν , solar- ν , neutrino astronomy....
- Great for physics beyond SM (nucleon decay, DM ...)
 - * *first 3-body nucleon decay search at SK*
[VT+ (SK), PRL, 2014]
 - * *several novel decay modes not in PDG*
[VT+ (SK), PRL, 2015]
- **SK-Gd (with Gadolinium) started** → aim to detect relic SN ν 's !

→ many new ideas for DM beyond WIMP annihilation/decay



Example 1: Dark Cosmic Rays

- Millicharge DM in vicinity of SN can get accelerated like regular cosmic rays
→ “boosted” DM with extended spectrum

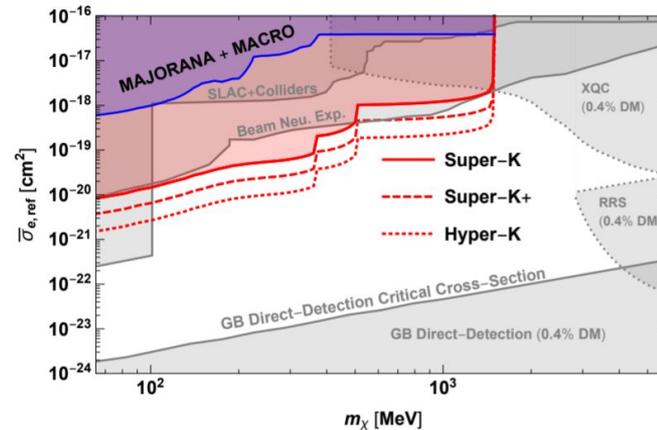
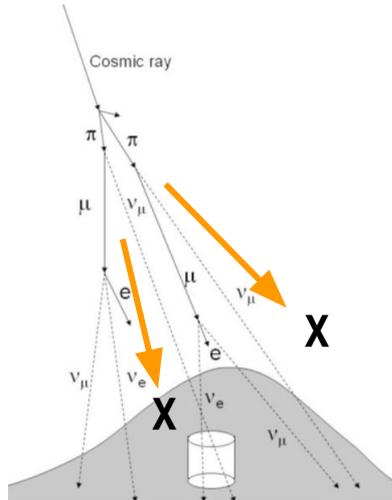


- Large q (μ -like) → “faint” Cherenkov ring, small q (ν -like) → electron scattering

[Hu, Kusenko, VT, PLB, 2016]

Example 2: Dark Matter from Atmospheric Collider

- Cosmic rays hitting atmosphere can produce millicharge DM from meson decays
→ “collider” is always ON, stable DM flux for all terrestrial experiments



- Idea with history → **completed first calculation of flux**

[Plestid, VT, Tsai, Bringmann, Kusenko, Pospelov, 2020]

Conclusions

Large underground dark matter and neutrino experiments constitute great sites of physics exploration beyond just their main target searches, with great synergy potential !