

Multi-Messenger Astronomy at



Mark Vagins

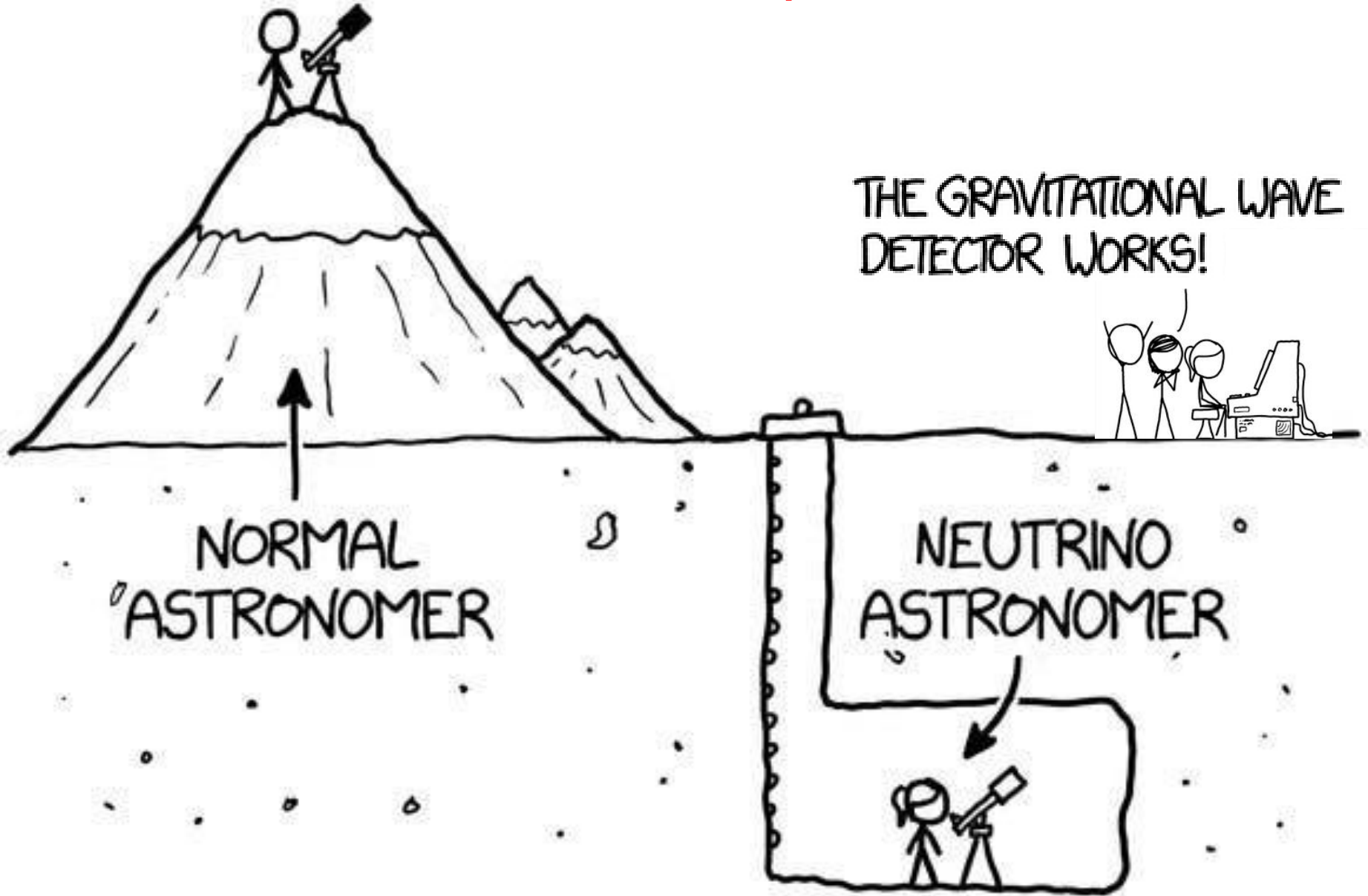
Kavli IPMU, UTokyo

2nd Synergies at New Frontiers Workshop

Kashiwa

March 25, 2024

This workshop in a nutshell...



As of Nov 1st, 2023, Kavli IPMU has a new Director:

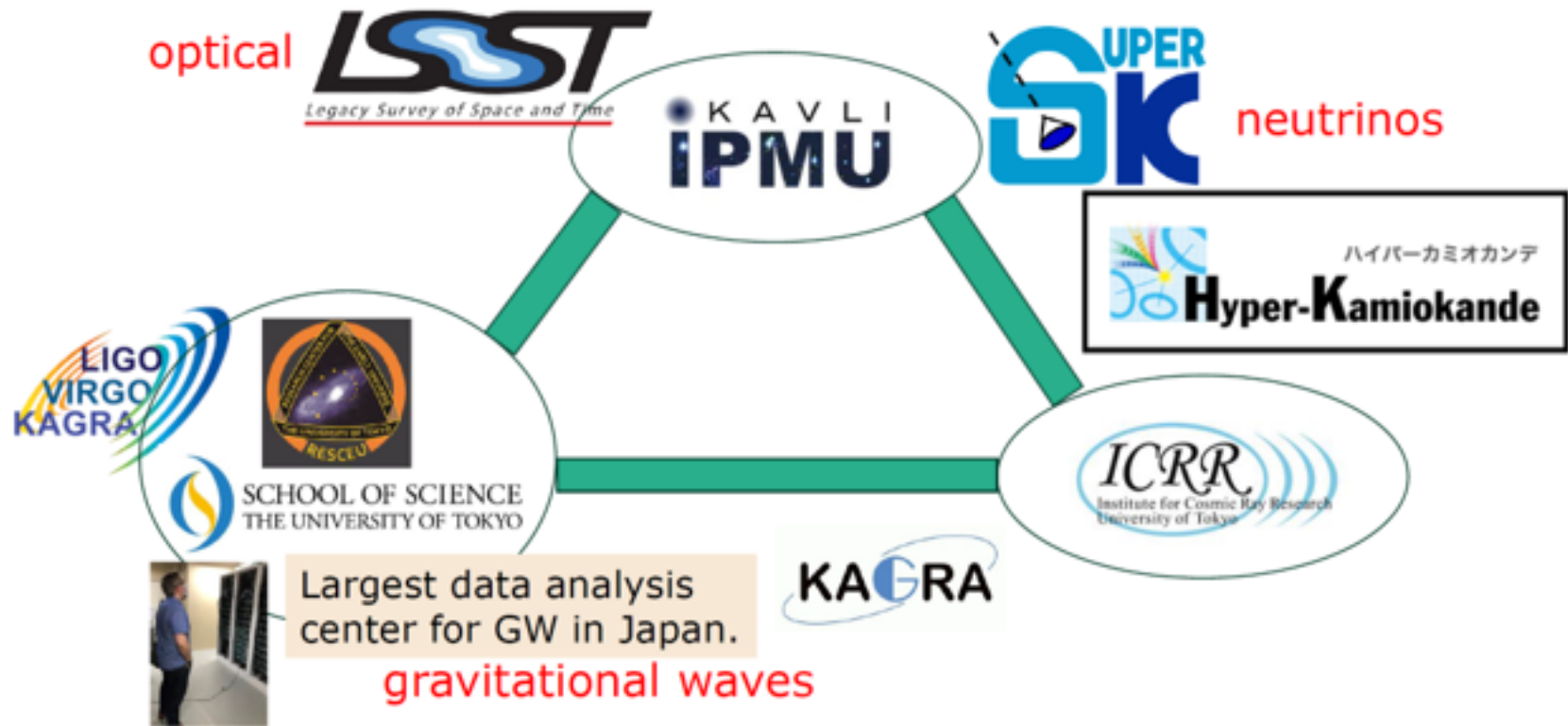
Jun'ichi Yokoyama

Yokoyama-san is also the Director of the Research Center for the Early Universe (RESCEU) at the University of Tokyo. He is an expert in gravity and cosmology, and served as the chair of the KAGRA Scientific Congress for the past two years.



Schematic of Director Yokoyama-san's Synergistic Vision

Multi-messenger Gravitational Wave Astrophysics

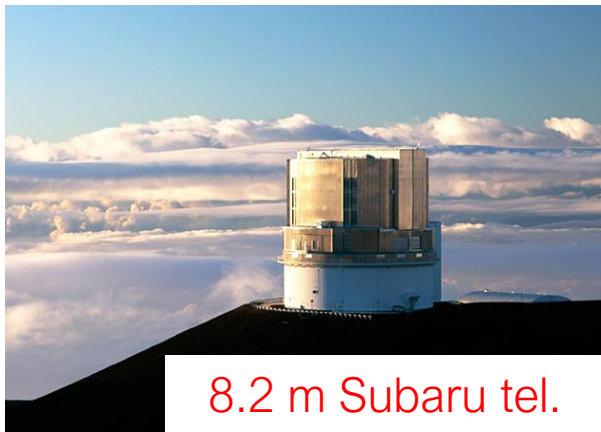


Breaking the barriers among these institutes, the U. Tokyo can be a unique place to lead the multi-messenger astrophysics in the world.

Now let's look at some of the various Kavli IPMU programs with a multi-messenger component...

Kavli IPMU's optical/IR role for multi-messenger astronomy

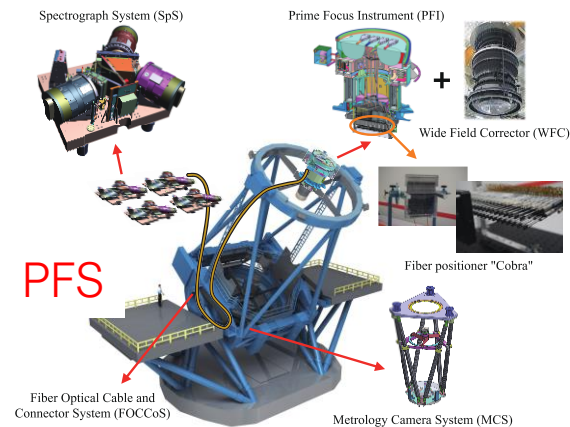
- Kavli IPMU is a leading institute of Subaru Hyper Suprime-Cam (HSC; imaging) and Prime Focus Spectrograph (PFS: spectroscopy) projects
- HSC/PFS are powerful instruments for a follow-up observation of transients (e.g. identifying GW counterparts)
- PFS is unique among other 8 meter-class telescopes
 - About 2400 fibers, 8.2 m wide aperture, wide field-of-view
 - Reconfigurable fibers (within ~2 min)
 - Now in the commissioning phase, and envision to start the operation in mid 2024
- Some of us are full members of the US-led RO LSST (imaging)



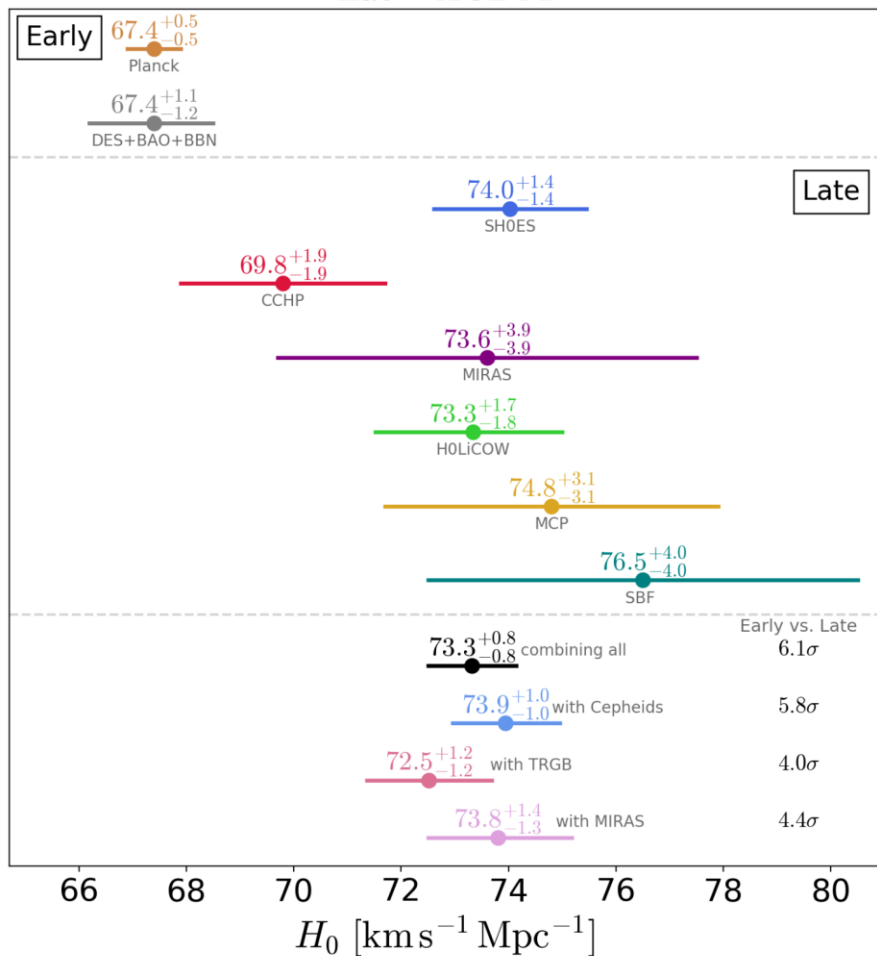
8.2 m Subaru tel.
(NAOJ)



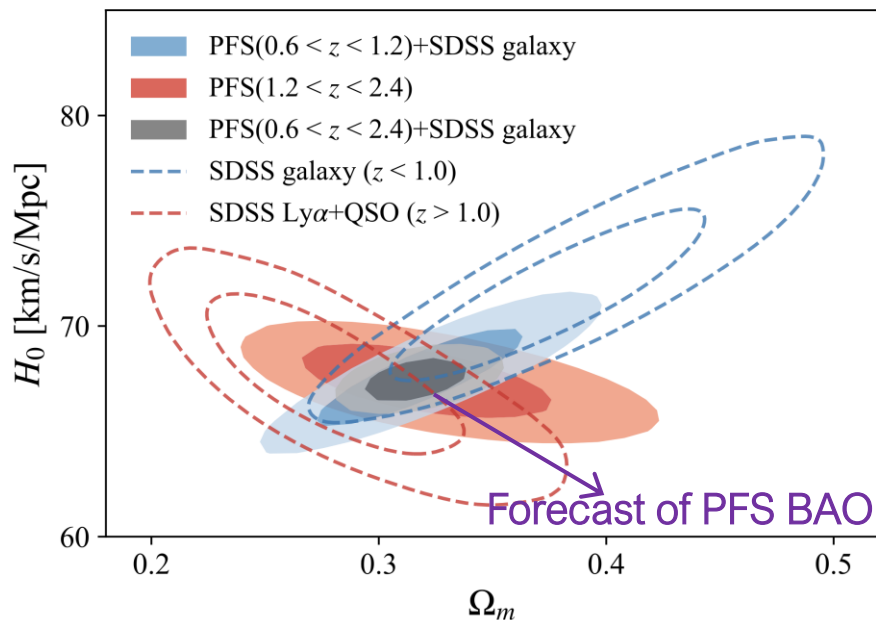
HSC



flat – Λ CDM



- “Hubble tension” might be a hint of Λ CDM breakdown – a new physics? e.g., early-dark energy
- Subaru PFS wide-field survey of emission-line galaxies can give an independent test of the Hubble tension from the BAO measurements, over $0.6 < z < 2.4$
- PFS BAO is very complementary to GW standard siren
- Profs. Yokoyama and Sasaki for GW/GR physics



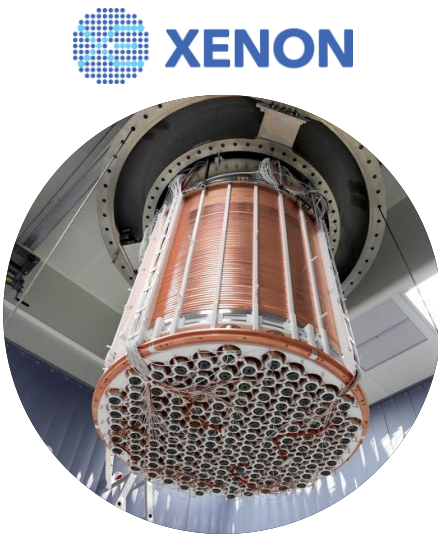
XENONnT & DARWIN/XLZD:

Dark Matter detectors also record SN neutrino bursts

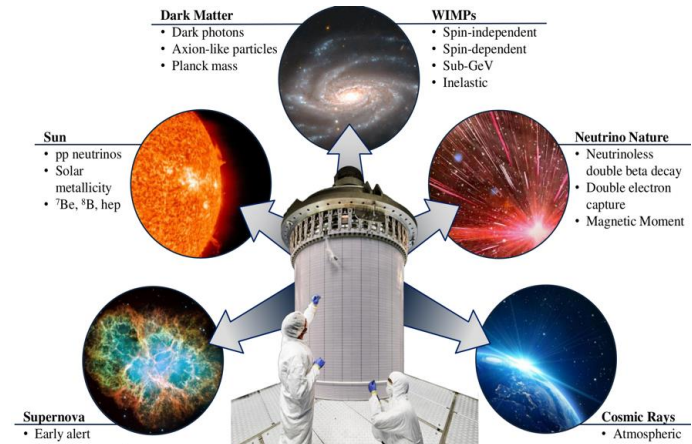
Kai Martens

Masaki Yamashita

Large Liquid Xenon Detector in the underground laboratory



The future: DARWIN / XLZD



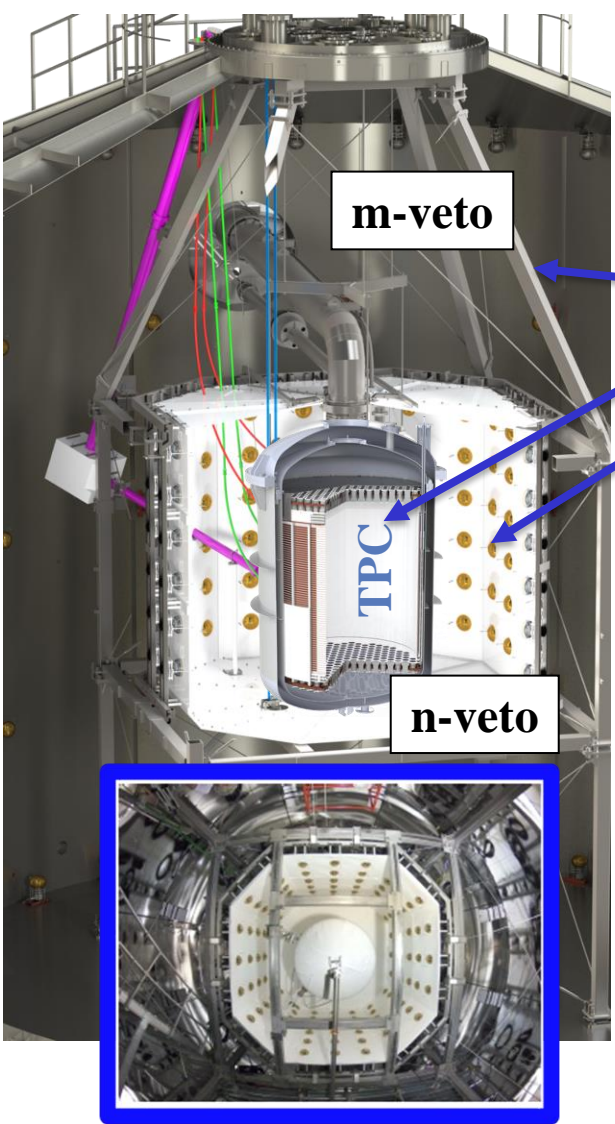
XENONnT:

one of the most sensitive **WIMP** dark matter detectors

- ongoing experiment, located at LNGS in Italy
- **5.9 t liquid xenon** target

DARWIN/XLZD:

Ultimate detector with **50 t** or more for **Multi-purpose rare-event search** in 2030's



XENONnT: 3 detectors

Xe Time Projection Chamber

- 5.9 t LXe target (WIMP detector)

Neutron and muon veto systems: Cherenkov Detectors

- 700 t water tank

- 84 (120) PMTs in nVETO (μ VETO)

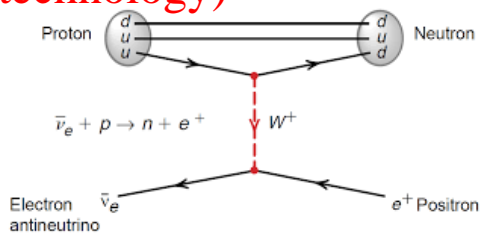
n-veto

- Highly reflective ePTFE and ultra-pure water to maximize light-collection efficiency

- Tag neutrons through the neutron capture on hydrogen which releases a 2.22 MeV γ -ray

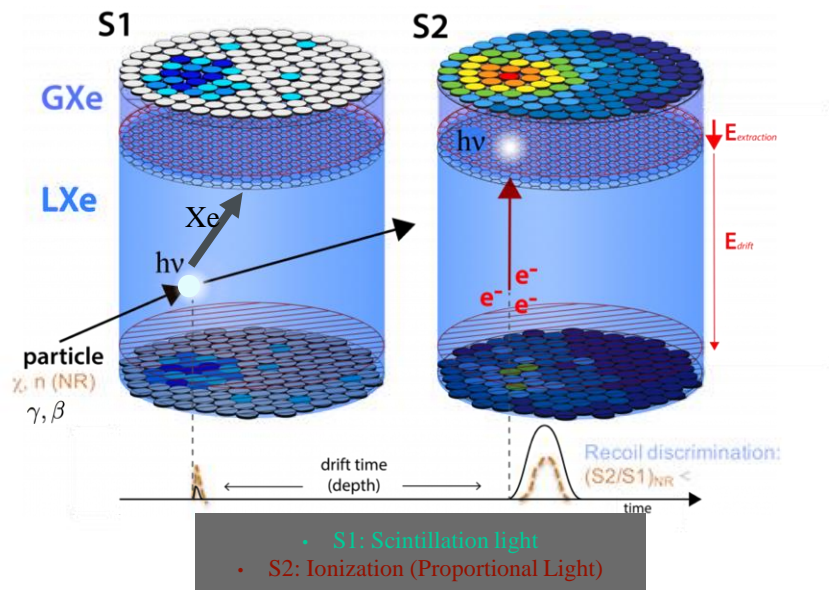
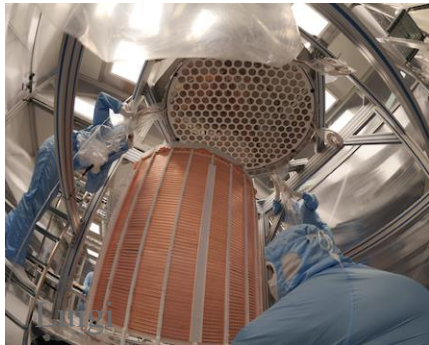
Have recently added Gd to the water (EGADS, SK-Gd technology)

Supernova Neutrino Detection through inverse-beta decay channel

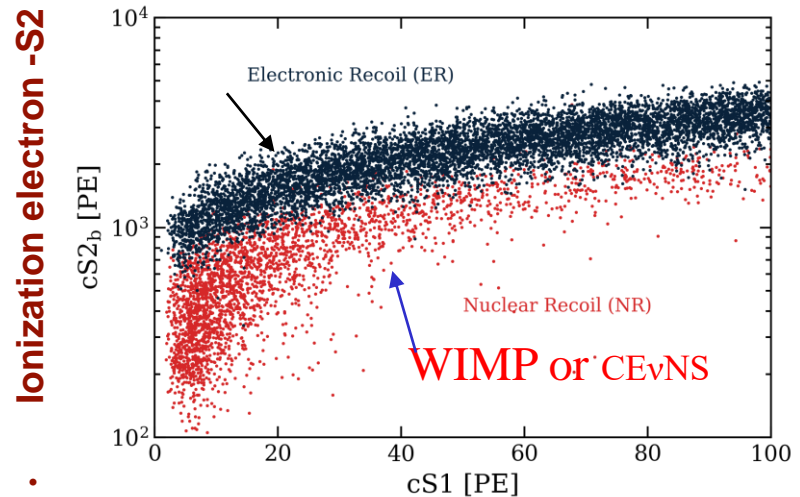


How can we detect SN neutrinos with a Dark Matter Detector?

- Signal from Scintillation Light(S1) and Charge (S2)
- **3D Position Reconstruction**: x-y (S2) and z (drift time)
- Identify multiple site events: Compton Scattering, Neutron
- Particle identification: **the nuclear recoil signal (WIMP)** and **CEvNS** from electronic recoil (γ , β rays) with S2/S1 ratio ($> 99\%$)



Solar ν (e-scatter) and Background



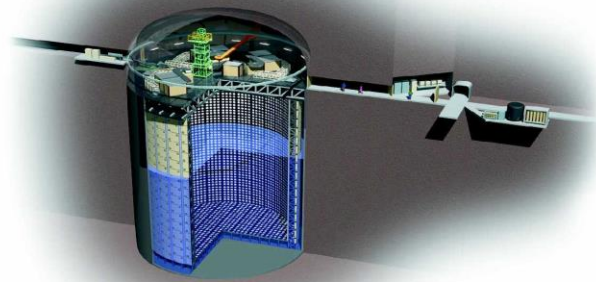
- **Scintillation light - S1**

Neutrinos at Kavli IPMU and the WC Gadolinium Pipeline

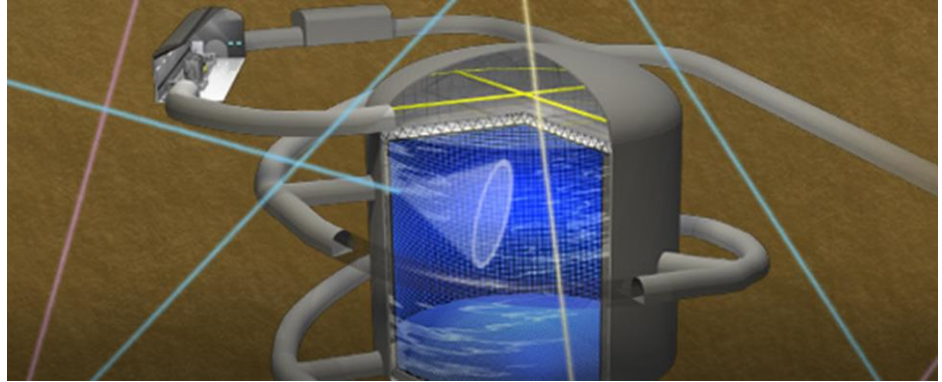
[Beacom and Vagins, *Phys. Rev. Lett.*, **93**:171101, 2004]
(570 citations as of today)

EGADS
(200 tons)

↓ 2020



↓ 203x (hopefully!)

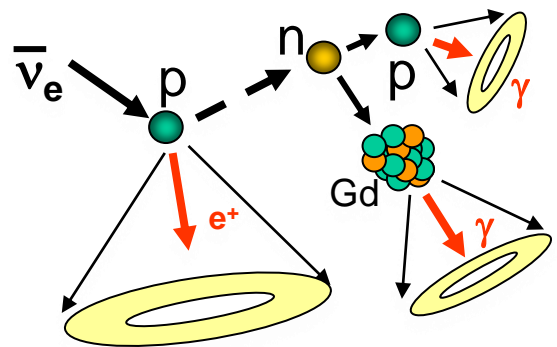


Super-Kamiokande
(50 ktons)

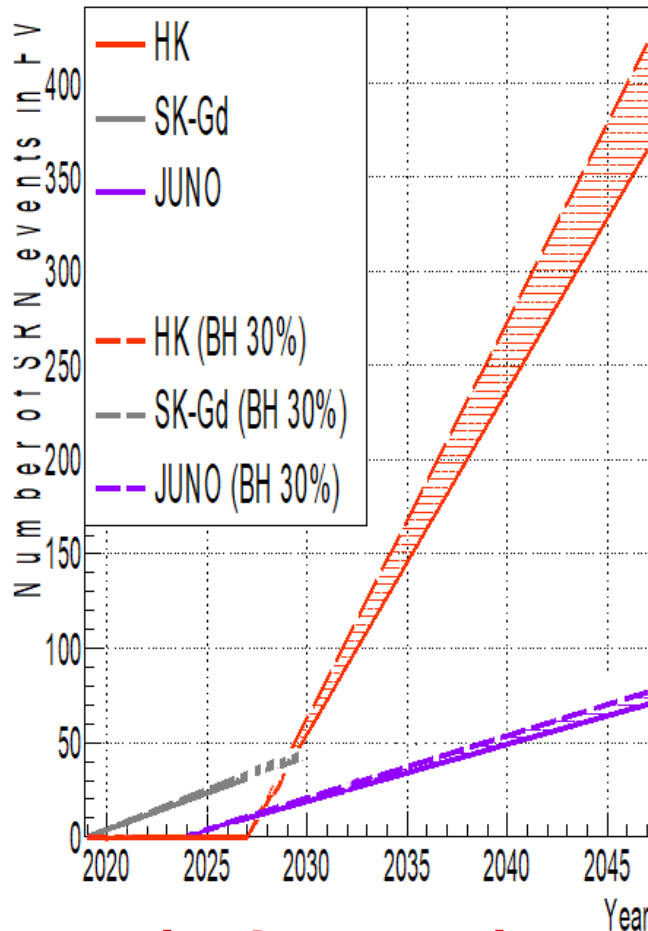
EGADS and Super-K are now both Gd-loaded in Japan, along with ANNIE at Fermilab (US) and the veto region of XENONnT in Gran Sasso (Italy).

Other projects using this Kavli IPMU/ICRR tech are under construction at Brookhaven (US), CERN (EU), and Boulby (UK).

Hyper-K
(258 ktons)



Expected number of Diffuse Supernova Neutrino Background (DSNB) events in SK/JUNO/HK



~4 events/yr in HK w/ H tag

- Stellar collapse
- Star formation rate
- Heavy element synthesis

SK-Gd (22.5 kton H₂O + Gd)

[neutron tagging by Gd-loading]

Started Gd data-taking in 2020

Aim for the first discovery

JUNO (20 kton LS)

Start data-taking in 2024(?)

Hyper-K (187 kton H₂O)

Start data-taking in 2027

Aim for the precise flux and energy spectrum measurement

Adding gadolinium to HK is being preserved as a future upgrade option → >10 DSNB events/yr

Main 200-ton Water Tank
(224 50-cm PMT's + 16 HK test tubes)

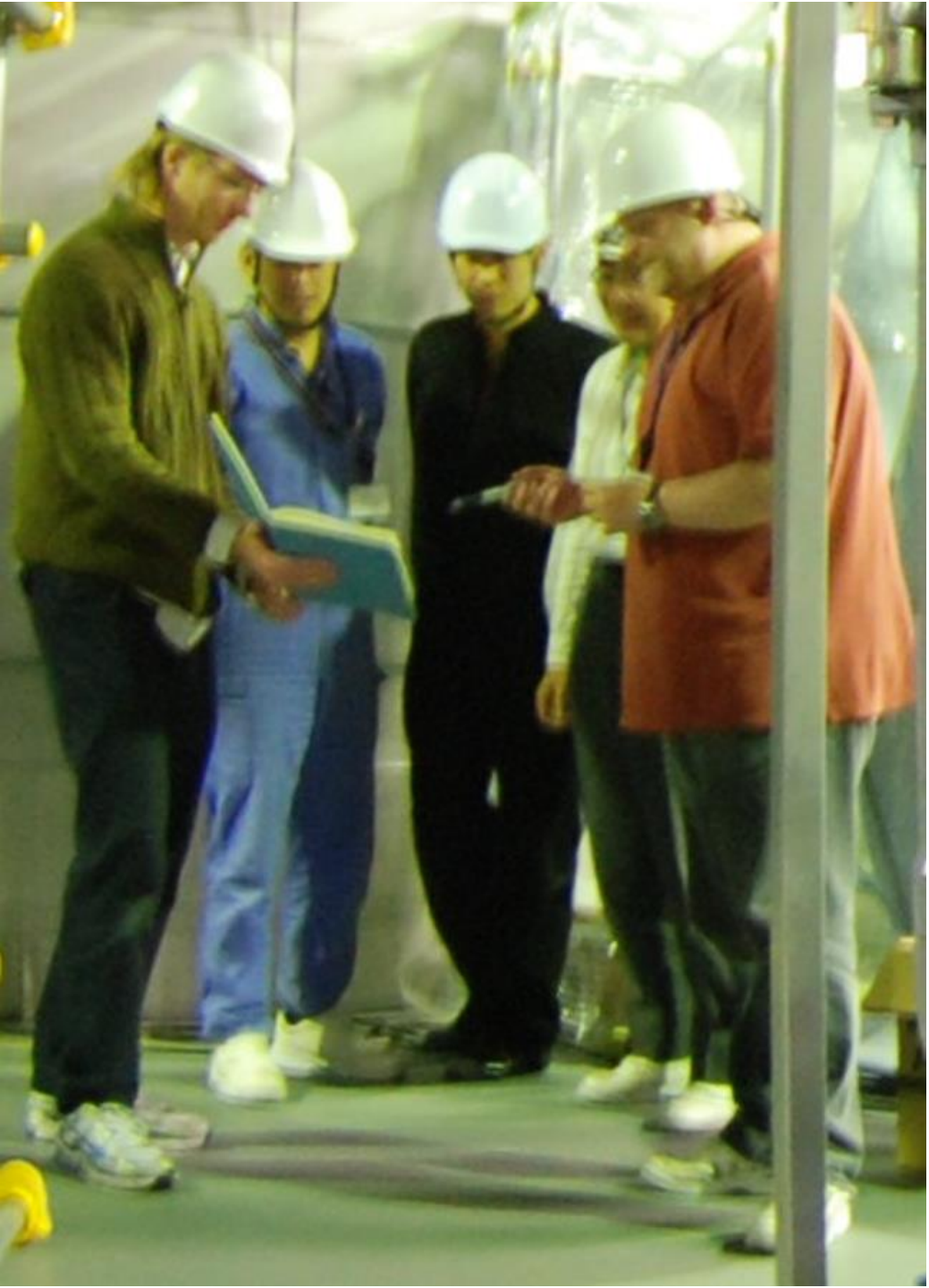
**EGADS
Laboratory
in Kamioka**



15-ton Gadolinium
Pre-treatment
Mixing Tank

Selective Water+Gd
Filtration System

Worldwide, over ¥十五億 (\$10M) has been spent developing and proving the viability of the Gd-in-water concept.



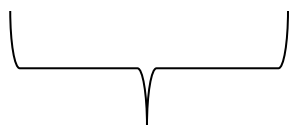
Mark Vagins

Masayuki Nakahata

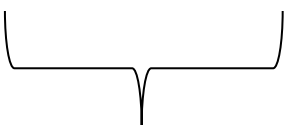
Takaaki Mori

Yusuke Koshio

Lluis Marti



Speaking
Today



Speaking
Tomorrow

With an R&D program of mostly long-duration tests, EGADS also functions as a dedicated, Gd-loaded SN detector. Its realtime alerts are open to the public.

~90,000 ν events
@ Betelgeuse

~40 ν events
@ G.C.

EGADS is now the lowest latency SN neutrino detector in the world.
We'll send out an announcement within *a few seconds* of a MW SN neutrino burst's arrival!

<https://www-sk.icrr.u-tokyo.ac.jp/~egofl/>

EGADS/HEIMDALL

https://www-sk.icrr.u-tokyo.ac.jp/~egofl/

200-ton EGADS/HEIMDALL

Galactic Supernova Monitor

Page loading time (local time):	Monday, 25 March 2024 00:10:18
HEIMDALL status update time (JST):	Monday, 25 March 2024 00:10:12

Status: No supernova detected

Page loading time should be ~ 2 seconds
HEIMDALL update time should be < 2 minutes
(In case of supernova alarm will fired within < 10 seconds from the burst onset)

A prompt email is sent as soon as a supernova is detected.
More information is sent by email within about less than 30 minutes.
If you want to receive them or have questions/suggestions send an email to: martillu_at_suketto.icrr.u-tokyo.ac.jp

Sound Test

**Sorry, but there was no Milky Way supernova
while I was preparing my talk last night.**

Please see Lluís Martí's dedicated talk tomorrow for an update!

So, thank you
for having me
here today.

Let's keep
watching the
skies together!

