Astro-particle Physics & Cosmology Summary

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https://yzhxxzxy.github.io

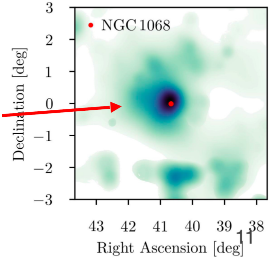
The 29th International Workshop on
Weak Interactions and Neutrinos (WIN2023)

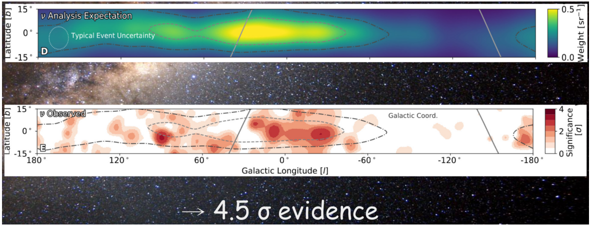
July 8, 2023, Zhuhai

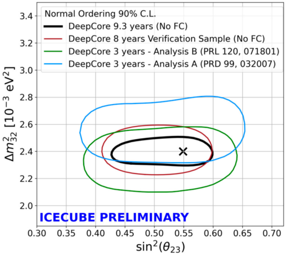
Experimental Talks

GeV to PeV Neutrinos in IceCube (Shiqi Yu)

- Evidence for **neutrinos** from **Seyfert galaxy NGC 1068**
- Looking for neutrinos from **more Seyfert galaxies**
- Observation of **neutrinos** from the **Galactic plane**
- Study on **neutrino oscillations** with DeepCore gives one of the world's best constraint on Δm^2_{32}

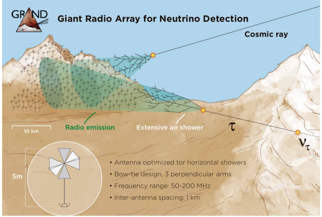






GRAND: Giant Radio Array for Neutrino Detection (Ramesh Koirala)

- **GRAND** is a **radio detector**
- **CRs**, **γ-rays**, and **neutrinos** produce **extensive air showers**, from which **radio waves** are emitted mainly due to the **geomagnetic** and **Askaryan effects**
- 1st phase of **GRANDProto300** under construction will be the pathfinder for **GRAND10k**



Study for New Physics

- Neutrino-nucleon cross-section at UHE
- Neutrino decay
- Lorentz-invariance violation
- Active-sterile neutrino mixing
- Pseudo-Dirac neutrinos
- Indirect detection of dark matter or energy
- etc.

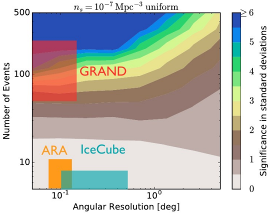
New Radio Emission Mechanism

- geosynchrotron: clover leaf pattern

Significance of point source detection

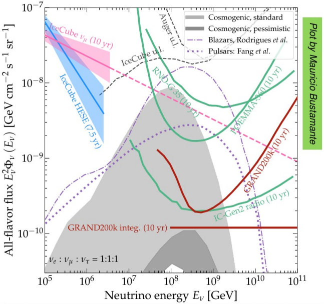
100s of UHE neutrinos in 3 years

~ 0.1° angular resolution



K. Fang et al., JCAP (arxiv:1609.08027)

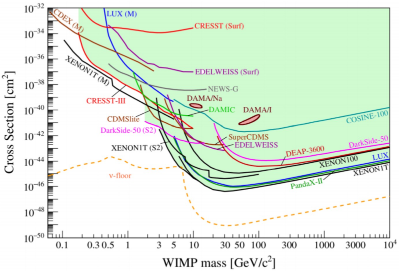
K. Kotera, ICRC2021 (arXiv:2108.00032)

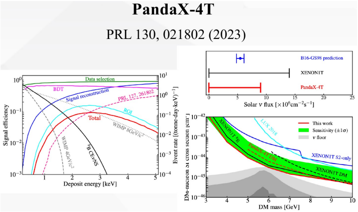


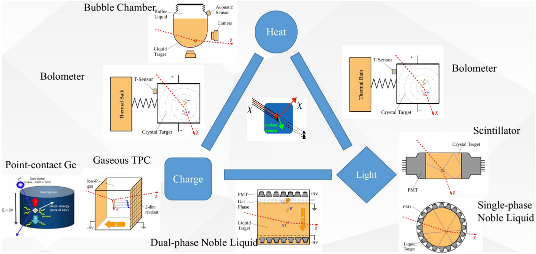
Guaranteed to detect UHE cosmogenic neutrino

Dark Matter Direct Search Experiments (Qing Lin)

- **Efforts** have been **paid heavily** on > 10 GeV **heavy DM** and < 10 GeV **light DM** searches
- **No positive signal found yet**
- **Bolometer** and **semi-conductor** are leading the search for **light DM**
- **Liquid xenon time projection chamber** is leading the search of > 10 GeV **DM**
- DM detectors are getting used in **neutrino measurements**

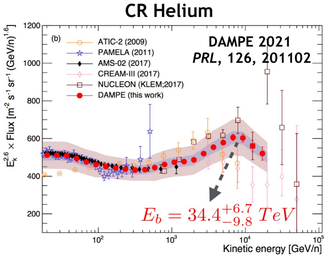


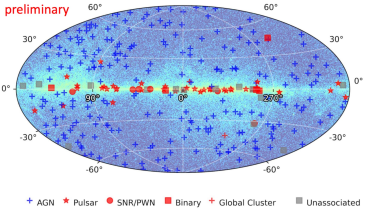




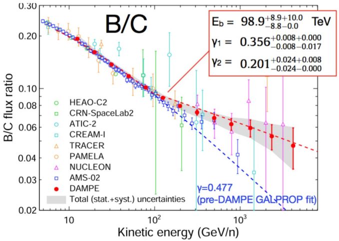
DAMPE: 7 Years in Space (Chuan Yue)

- **DAMPE** reveals **spectral softening features** in **CR nuclei** at $\sim \mathcal{O}(10)$ TeV, which are likely an imprint of a **nearby CR source**
- **DAMPE** shows unexpected **hardening features** at ~ 100 GeV/n in the $\mathrm{B/C}$ and $\mathrm{B/O}$ **spectra**
- ≥ 300 **γ-ray sources** are detected, including **Fermi bubbles** and **Galactic center excess**
- **Stringent upper limits** on **DM annihilation/decay** into **monochromatic γ-rays** are obtained





Source Type	Number
AGN	236
Pulsar	40
SNR/PWN	6
Binary	5
Global Cluster	2
Unassociated	14
Total	303



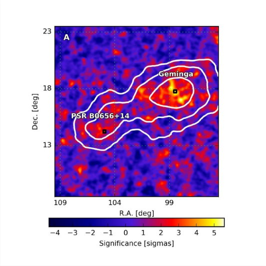
Significance ~ **5.6σ** (GEANT), 4.4σ (FLUKA)

HAWC γ-ray Observatory (Ramiro Torres-Escobedo)

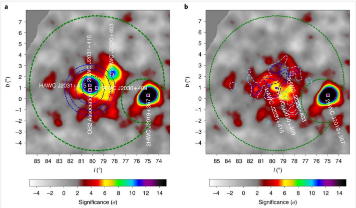
HAWC reveals **TeV halos** around **nearby pulsars**, and detects **TeV emission** from **microquasar SS433**

HAWC firstly observes **γ-ray emission** at 1–100 TeV in the **Cygnus cocoon region**, which are likely emitted from **freshly accelerated CRs** with 10 TeV–1 PeV

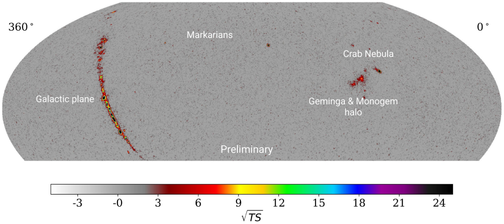
25/18/4 sources with $> 56/100/177$ TeV γ-rays are found in the **HAWC Pass 5 data** (2400 days)



Science 2017 Vol 358, Issue 6365 pp. 911-914

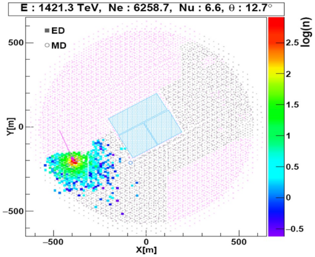


Nature, volume 5, pages 465–471 (2021)

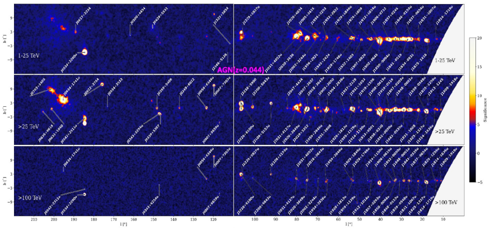


γ-ray Astronomy Results from LHAASO (Zhe Li)

- ✨ **LHAASO** detects a **UHE photon** with 1.42 PeV from the **Cygnus region** and **43 UHE γ-ray sources**
- 🌟 **LHAASO** finds a **TeV afterglow** from a narrow jet in the **extremely bright GRB 221009A**
- **LHAASO** measures **diffuse γ-ray emission** of the **Galactic plane** from 10 TeV to 1 PeV
- 🪐 **Constraints** on **LIV** and **decaying DM** are given

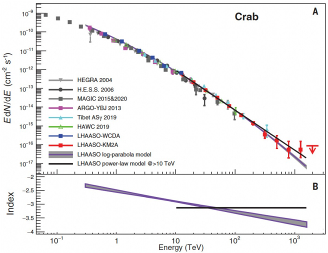


82 sources with the Galactic latitude |b|<12°



LHAASO's first catalog 13

LHAASO Coll, 2023, arXiv:2305.17030



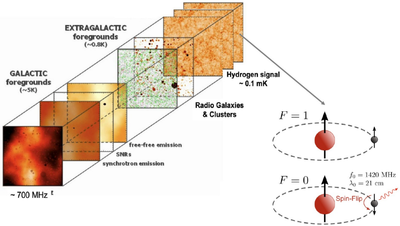
LHAASO Coll, 2021, (Science, 373,425

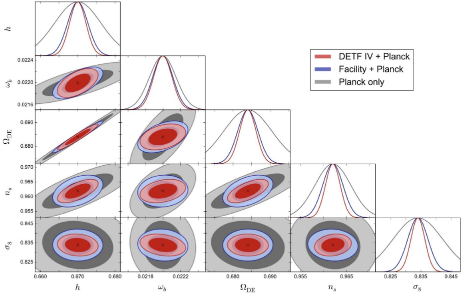
Cosmology with Square Kilometer Array (Xin Wang)

COSMOLOGY WITH SKA-MID

- Medium-Deep Band 2 Survey
  - HI galaxy redshift survey $z \sim 0.4$
  - coverage: $\sim 5000\ \mathrm{deg}^2$
- *Wide Band 1 Survey*
  - a wide continuum galaxy survey
  - HI IM in the redshift range $z = 0.35 - 3$
  - coverage: $\sim 20{,}000\ \mathrm{deg}^2$
- *Deep SKA1-LOW Survey*
  - EOR
  - wide-shallow, a medium-deep, and a deep survey

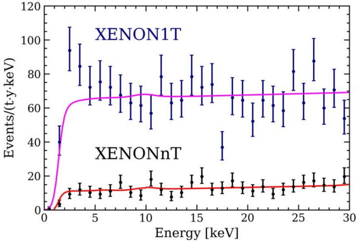
HI INTENSITY MAPPING





XENONnT: Dark Matter and Beyond (Shixiao Liang)

- **XENONnT LowER Result**: **no excess**
  - Data agree with background-only model
  - **XENON1T excess excluded by 4σ**
- **XENONnT WIMP SI search** result
  - 2.58×10^{-47} cm^2 (90% C.L.) at 28 GeV/c^2
  - $1.6\times$ **improvement** from XENON1T with shorter life time

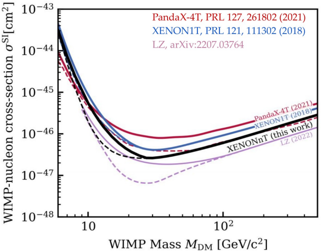


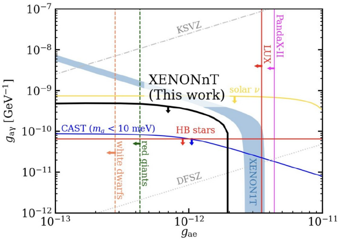
XENONnT Upgrades

Reusing XENON1T infrastructure

×3 Active Volume

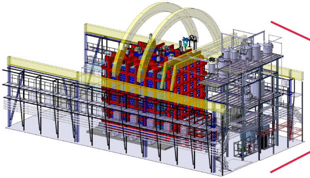
1/6 Backgrounds

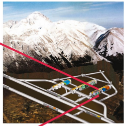




DarkSide-20k Experiment (Tianyu Zhu)

The DarkSide-20k Experiment

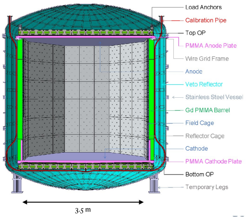




- Below ~1400m of rock (3400 m.w.e)
- Muon flux reduction factor ~10^6

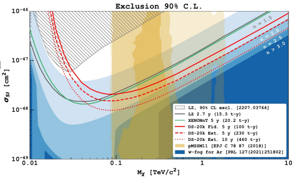
The DarkSide-20k Inner Detector

- TPC: 50 tonnes of UAr depleted in ^{39}Ar, 20 tons in fiducial volume.
- Active neutron veto integrated lateral TPC walls with Gd-loaded PMMA (acrylic)
- Reflector cage cover the TPC inner volume using TPB coated ESR foils
- Large SiPM based photo-detection covers the top and bottom of the TPC



Sensitivity to WIMPs

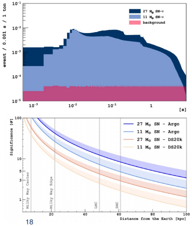
- Projected 6.3×10^{-48} cm² sensitivity for DS-20k SI WIMP-nucleon cross-section with a nominal 20x10 t y exposure.
- Only 0.1 instrumental background events in 200 t yr
- Expected neutrinos: 3.2 events in 200 t yr
- Low mass WIMPs covered by Maxim Gromov



Sensitivity to CCSN Neutrinos via CEνNS Process

- During a core collapse supernova, 99% of the energy is emitted through neutrinos (~10^{53} erg)
- Neutrinos via CEνNS process are observed as low-energy S2 only nuclear recoil signals.
- Expected signal and background in 8s for a SN burst at a distance of 10 kpc

	DarkSide-20k	Argo
11-$M_\odot$ SN-νs	181.4	1396.6
27-$M_\odot$ SN-νs	336.5	2591.6
^{39}Ar	4.3	33.8
external background	1.8	8.8
single-electrons	0.7	5.1

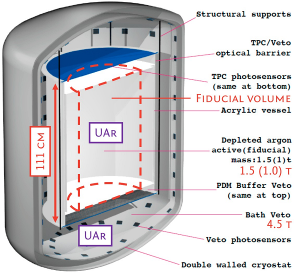


JCAP03(2021)043

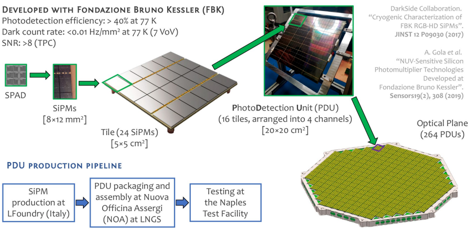
UCDAVIS

Light DM Searches with DarkSide-LowMass (Maxim Gromov)

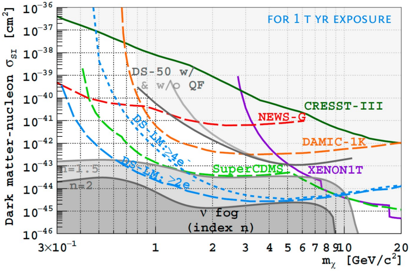
- **DarkSide-LowMass** is a **well-optimized LArTPC** that will **significantly increase** the search capabilities for **light DM particles**
- **Several years of data taking** are enough to achieve **main physical results**
- Almost all technologies and methods are **developed** and **available**



Low-background SiPMs developed for DarkSide-20k



Projected and current 90% C.L. upper limits on spin-independent DM-nucleon scattering

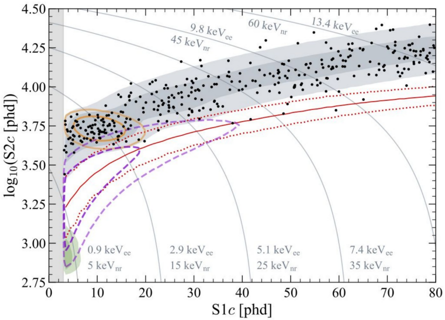


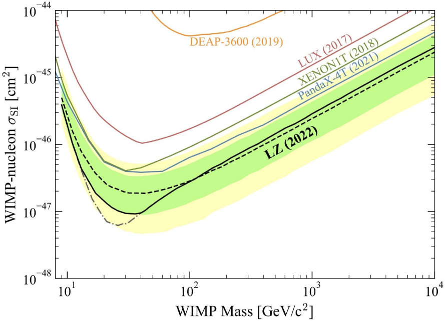
First Results from the LZ Experiment (Dongqing Huang)

🎂 **LZ detectors** are performing well and **backgrounds** are **within expectations**

🎉 With its **first science run**, LZ has achieved **world-leading WIMP sensitivity**, and been demonstrated to be the most sensitive dark matter detector ever built

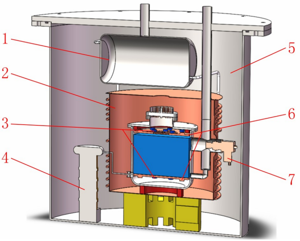
🎄 LZ plans to take **1000 live days of data** (**x17 more exposure**)



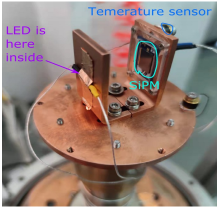


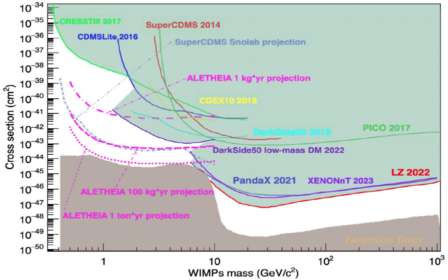
ALETHEIA, a Low-mass DM DD Experiment (Junhui Liao)

- **ALETHEIA**: A Liquid hElium Time projection cHambEr In dArk matter
- **DM signals** do not necessary show up as **NR recoil only**: **ER only** and **ER & NR coexistence** also possible



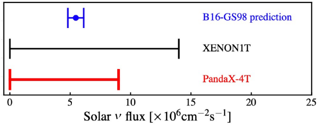
- The ALETHEIA project is supposed to only have **single-digit number** of **ER** and **NR backgrounds** with a 1 ton · yr **exposure**, and is **sensitive to any kinds of DM signal combinations**
- The viability of a **single-phase LHe TPC** has been demonstrated

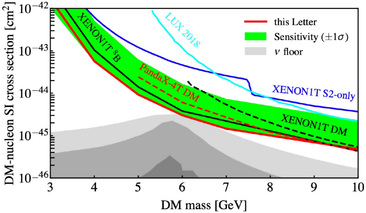


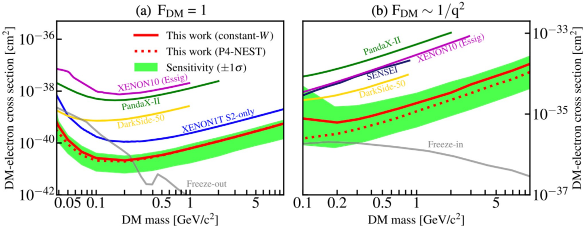


PandaX-4T: Solar Neutrinos and Low-mass DM (Wenbo Ma)

- The **low-energy analyses** in the **PandaX-4T commissioning** run yield **world-leading sensitivity** for **solar ^{8}B CEvNS** and **low-mass dark matter**
- Analysis on **S2-only channel** gives **better DM-electron constraints** at low-mass region
- **Low-threshold analysis techniques** will be further employed in science run 1



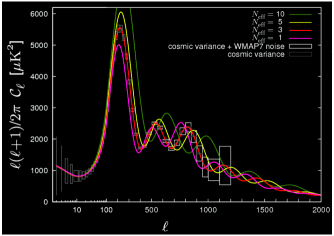


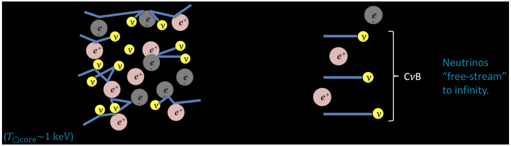


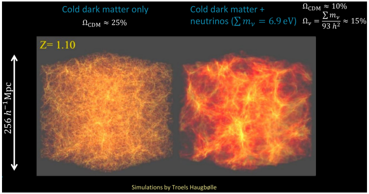
Phenomenological Talks

Neutrino Physics & Cosmology (Yvonne Y. Y. Wong)

- Formation of the **CνB**
- Impacts of the **number of neutrino families** $N_{\rm eff}$ on the **Hubble rate**, **BBN**, and **CMB**
- **Neutrino masses $\sum m_\nu$** & **large-scale structure**
- Neutrino free-streaming & **CMB**
- **Neutrino self-interaction** & the **H_0 tension**
- **CMB** lower bounds on the **neutrino lifetime**



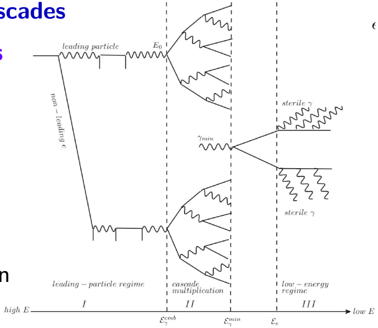




Precision cosmological observations have allowed us to infer the properties of the **cosmic neutrino background**, from which to determine neutrino properties, e.g., **masses**, **effective number**, **non-standard interactions**, **lifetime**

Multimessengers in Probing the HE Universe (Arman Esmaili)

- A lot can be learned from **electromagnetic cascades**
- There is a **tension** between **IceCube neutrinos** and **Fermi-LAT EGB**
- The tension points toward **"opaque sources"**
- It requires **high densities** to make the source **opaque to γ-rays**, while the **protons** still can be **accelerated to** ~ 100 PeV
- Extension of EGB data to **multi-TeV range** can further constrain the sources



Neutrino and gamma-ray connection

Any source that produces neutrinos, should produce gamma-rays also:

$$p + p \to \pi^\pm + X \quad \pi^\pm \to \mu + \nu,\ \mu \to e + \nu + \bar{\nu}$$

$$p + \gamma \to \pi^\pm + X \quad \pi^\pm \to \mu + \nu,\ \mu \to e + \nu + \bar{\nu}$$

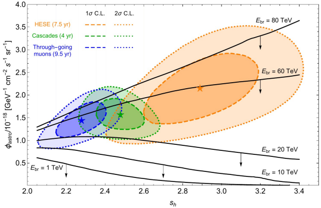
$$\pi^0 \to 2\gamma$$

More precisely (conservative assumption)

$$\frac{1}{3}\sum_\alpha E_\nu Q_{\nu_\alpha}(E_\nu)\bigg|_{E_\nu = E_\gamma/2} = \frac{K_\pi}{4} E_\gamma Q_\gamma(E_\gamma)$$

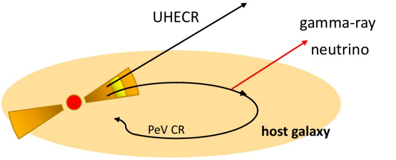
~ 3σ tension for E_{br} = 10 TeV

~ (4-5)σ tension for E_{br} = 1 TeV

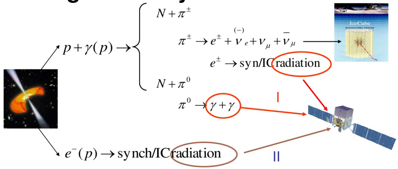


Origins of High Energy CRs/Neutrinos (Zhuo Li)

- Are there **neutrinos** from **LHAASO sources** as **PeVatrons**?
  - The **neutrino flux** is **too weak** to **present neutrino telescopes**
- Are there **γ-rays** associated with **TA CRs**?
  - Need **deeper γ-ray/neutrino** observations
- Are there **γ-rays** associated with **neutrinos**?
  - AGN jets/GRBs/TDEs **disfavored**
  - Starbursts/star forming galaxies **promising**



Neutrino--gamma-ray connection

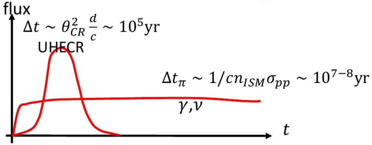


Connections:

I. neutrino – secondary electron/gamma-ray

II. neutrino – primary electron/proton

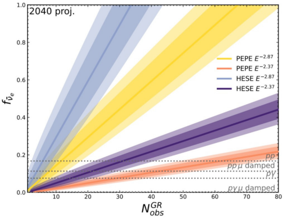
Temporary association: $\Delta t_\pi \gg \Delta t$



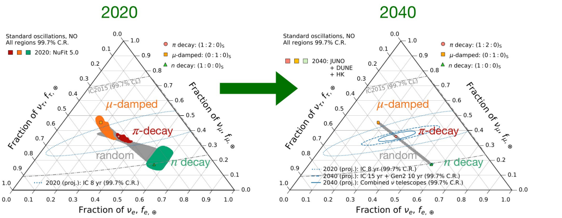
HE Astrophysical Neutrinos Measurements (Ningqiang Song)

- Determining **neutrino flavor composition** at the source
  - **Pion decay** well separated from **muon damped** by 2040
- **Breaking $pp/p\gamma$ degeneracy** with **Glashow resonance**
- Probing **new physics** and with future measurements
  - Search for **neutrino decays** with neutrino telescopes and oscillation experiments
  - Probe **micro black holes** at neutrino telescopes

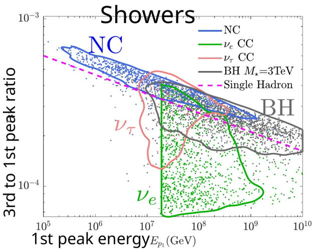
All future ν telescopes



Liu, **NS**, Vincent, 2304.06068



NS, Li, Argüelles, Bustamante, Vincent, JCAP/2012.12893

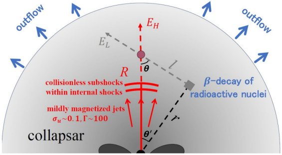


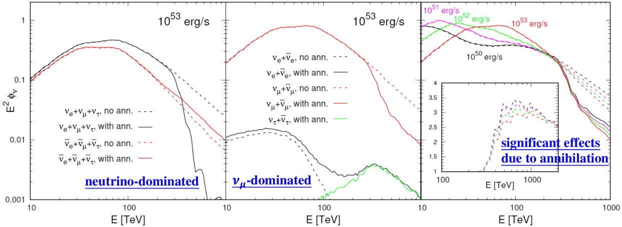
Mack, **NS**, Vincent, JHEP 2019/1912.06656

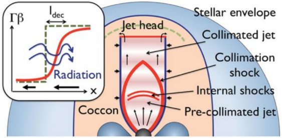
HE Neutrinos & r-process Nuclei from Collapsars (Gang Guo)

Revisit **HE neutrino production** inside the **progenitor star** of **collapsars** and investigate a novel connection between **HE** & **LE** neutrinos from **collapsars**

- HE neutrino production at **jet-induced shocks** in GRBs/CCSNe
- HE neutrino production **deep inside progenitor star**
- HE neutrino production at **internal shocks** inside progenitor star
- **Antineutrinos** from **β-decay** of synthesized elements
- **Oscillations** of **LE antineutrinos**
- **Neutrino pair annihilation**





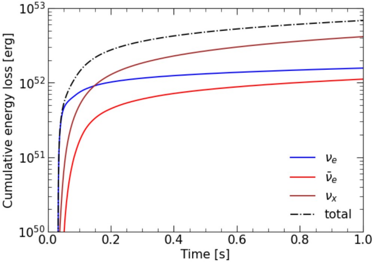


Murase+13

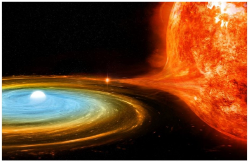
Neutrinos from AIC of White Dwarfs (Chun-Ming Yip)

Accretion-Induced Collapse (AIC) and **explosion** of **ONeMg white dwarfs** is the **3rd supernova model**, which have not directly observed

- **AIC mechanism**: Collapse & Core Bounce
- **Simulation of AIC** including **neutrino production** and **transport**
- A **very bright neutrino burst** is associated with **AIC**
- **AIC** could be **distinguished** from **standard supernova models**



ONeMg
~~CO~~ white dwarf

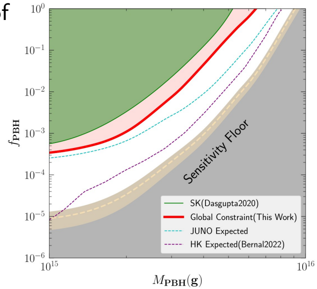


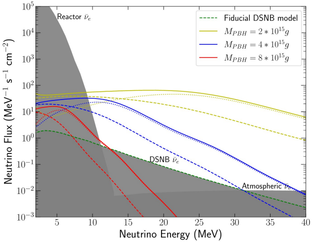
donor

model	Type Ia	CCSN	AIC
progenitor	CO white dwarf	massive star	ONeMg white dwarf
neutrino signal	faint	bright	bright
EM signal	bright	bright	faint

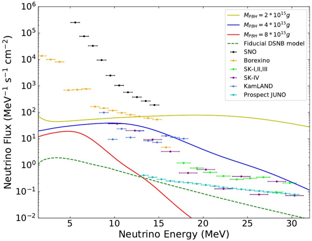
Sensitivity Floor for PBH Neutrino (Qishan Liu)

- **Primordial black holes (PBHs)** could be a fraction of **dark matter** and emit **neutrinos** by **Hawking Radiation**
- **Null observations** of **antineutrino flux** from several neutrino detectors are used to set **new constraints** on PBHs as a DM candidate
- The **DSNB** serves as an **irreducible background** that forms a **sensitivity floor** in PBHs parameter space





Atmospheric $\bar{\nu}_e$[K. et al.2018]
DSNB $\bar{\nu}_e$[Moller2018]
Reactor $\bar{\nu}_e$[Battistoni2005]

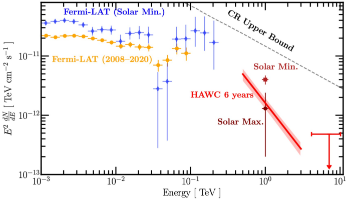


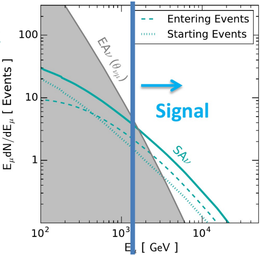
SNO[Aharmim et al.2004]
Borexino [M. et al.2021]
SK-I,II,III[K. et al.2012]
SK-IV[K. et al.2021]
KamLAND[Abe et al.2022]
JUNO[Abusleme et al.2022]
DSNB[Moller2018]

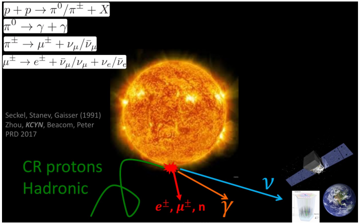
Solar Atmospheric Neutrinos (Kenny, Chun Yu Ng)

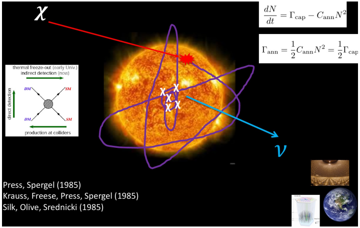
- **Solar atmospheric neutrinos** could be probed by **IceCube** and future **KM3NeT**
- The **solar atmospheric γ-ray flux** are **not fully explained**
- A **complete model** is necessary for **accurate neutrino flux**

Anomalous signals from the Sun may imply **new physics**, such as **dark matter**



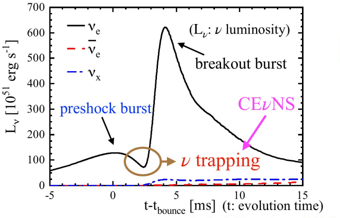






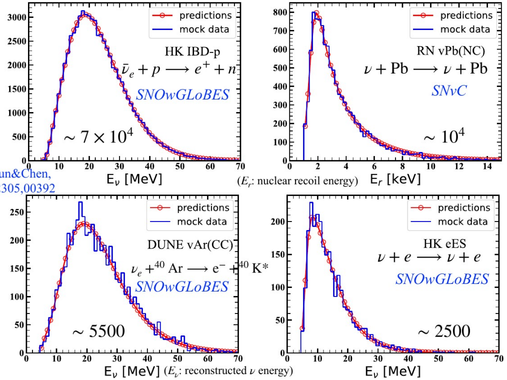
Supernova Neutrinos and Spectral Retrieval (Xurun Huang)

- The next **Galactic Core-Collapse Supernova (CCSN)** is **imminent**
- **Neutrinos** play a key role in **stellar core collapse**
- **Intense MeV neutrino flux** would last for 10 s
- 10^5 events in detectors lead to **a precision of a few percent** in the **retrieval of spectral parameters**



XH&Zha&Chen, ApJL (2021)

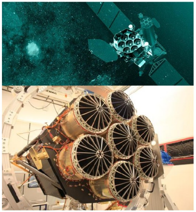
III. Detection and spectral retrieval (10 kpc)

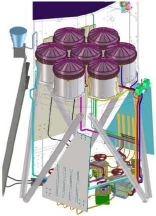


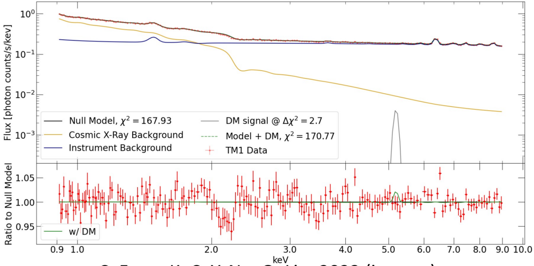
XH&Sun&Chen, arXiv:2305,00392

Constraining DM with eROSITA Early Data (Chingam Fong)

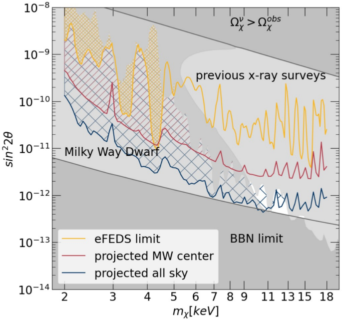
- **Early data** of **eROSITA** are used to produce **one of the best limits** on **DM lifetime** in **X-ray**
- By converting the limit into a few DM models **new parameter space** has been **ruled out**
- With **eROSITA planned data** release coming up in Sep. 2023, **even stronger limits** could rule out the **minimal neutrino standard model**







C. Fong, K. C. Y. Ng, Q. Liu, 2023 (in prep)



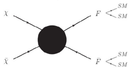
Forbidden DM Combusted @ SMBH (Yu Cheng)

🚫 Intrinsically, **forbidden dark matter cannot** be indirectly probed

🚡 However, by considering the **DM velocity increased** by **supermassive black holes**, **Fermi-LAT data** for **point sources** around **SMBH** can be used to test **forbidden DM**

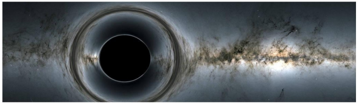
- Core: Isothermal Gas
- Spike: Conductive Fluid
- Density and Velocity Profile
- Fitting the Fermi-LAT Data
- Right-handed Neutrino Model

How to Test Forbidden DM?

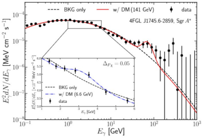


$\Delta \equiv (m_F - m_\chi)/m_\chi \sim 1\%$ ⇒ $v_d \sim 0.1$

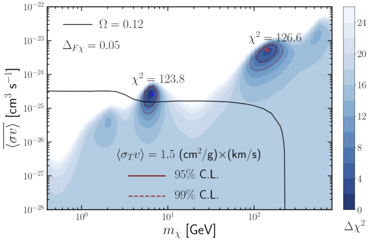
Typical DM velocity $\sim 10^{-3}$



$v^2 \sim \frac{GM}{r}$ ⇒ $v(r) \sim \frac{1}{\sqrt{r}}$ $\quad v_d \propto \frac{1}{\sqrt{r}}$



$\chi^2_{\text{BKG}} = 140.8$

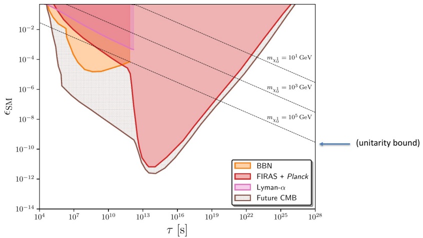


- **1^{st} Peak @ 6.6 GeV** $\quad \langle\sigma v\rangle = 2.56 \times 10^{-25} \text{cm}^3\text{s}^{-1}$
- **2^{nd} Peak @ 141 GeV** $\quad \langle\sigma v\rangle = 5.32 \times 10^{-24} \text{cm}^3\text{s}^{-1}$

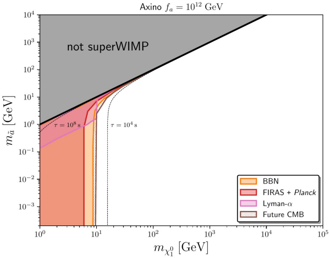
Cosmological Constraints on superWIMPs (Jan Hamann)

- 🏓 **SuperWIMP dark matter** interact so weakly with SM that it **never gets thermalized** in early Universe
- 🎾 **SuperWIMPs** could be produced via **WIMP decays**
- 🎳 **Cosmological observations** of **BBN**, **CMB**, **Lyman-α forest** can be used to probe **supersymmetric superWIMPs** like **gravitinos** and **axinos**

Gravitino superWIMP constraints

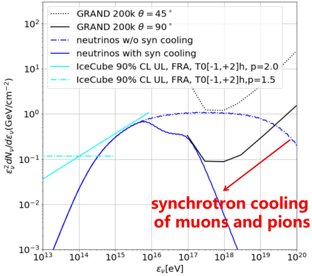


Axino mass – neutralino mass parameter space

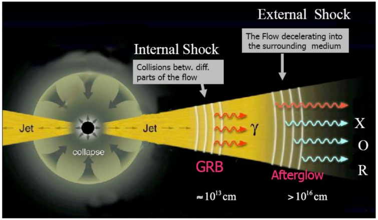


HE ν's & UHE CR Outburst from GRB 221009A (Haoning He)

- **γ-ray bursts** are candidate sources for **ultra-high energy cosmic rays**
- Only **protons** at the **high energy end** can escape from the burst and the host galaxy with a small deflection angle and delay time
- **Neutrons can escape easily**
  - **IceCube upper limit** on **neutrinos** from **GRB 221009A**
  - **Auger** and **TAX4** can constrain the model soon

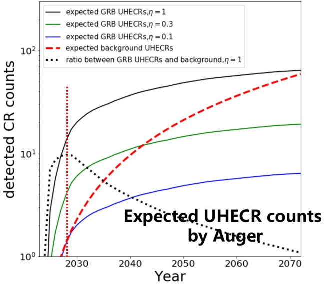


CR acceleration in GRBs



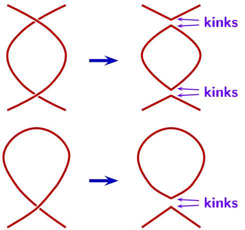
Credit: P. Meszaros

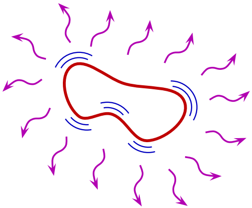
Gamma-ray bursts are short-duration flashes of gamma-rays occurring at cosmological distances.

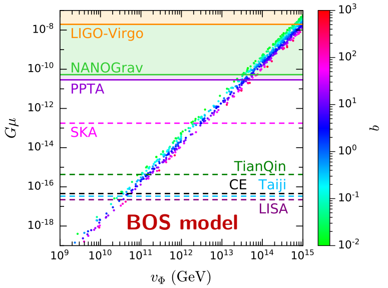


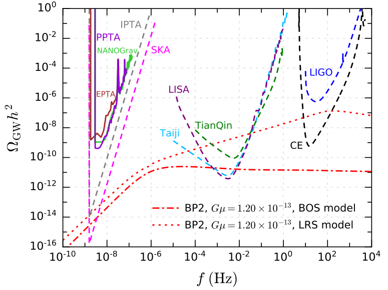
pNGB DM, Cosmic Strings, and GWs (Zhao-Huan Yu)

- A **UV-complete model** for **pNGB DM** with a **hidden** $\mathrm{U}(1)_\mathrm{X}$ **gauge symmetry** is studied
- A **UV scale** v_Φ **higher than** 10^9 GeV is required to suppress the **DM decay width** and **DM scattering off nucleons**
- The $\mathrm{U}(1)_\mathrm{X}$ **spontaneous breaking** would induce **cosmic strings** with **high tension**, resulting in a **stochastic GW background** with a **high energy density**







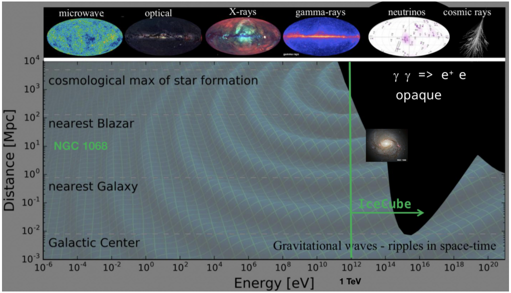


Summary

- There are **13 experimental talks** and **14 phenomenological/theoretical** talks covering **cosmology**, **neutrino astronomy**, **γ-ray astronomy**, **cosmic-ray astronomy**, **radio astronomy**, **dark matter searches**, and **gravitational waves**

Summary

- There are **13 experimental talks** and **14 phenomenological/theoretical** talks covering **cosmology**, **neutrino astronomy**, **γ-ray astronomy**, **cosmic-ray astronomy**, **radio astronomy**, **dark matter searches**, and **gravitational waves**
- We are in the **multi-messenger astronomy era!**
- The interplay among all viable messengers can help us **deeply explore new regimes** in **astrophysics**, **cosmology**, and **particle physics**



From Shiqi Yu's talk