CF7. Cosmic Probes of Fundamental Physics

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Early Career Representatives: Kristi Engel and Tiffany Lewis

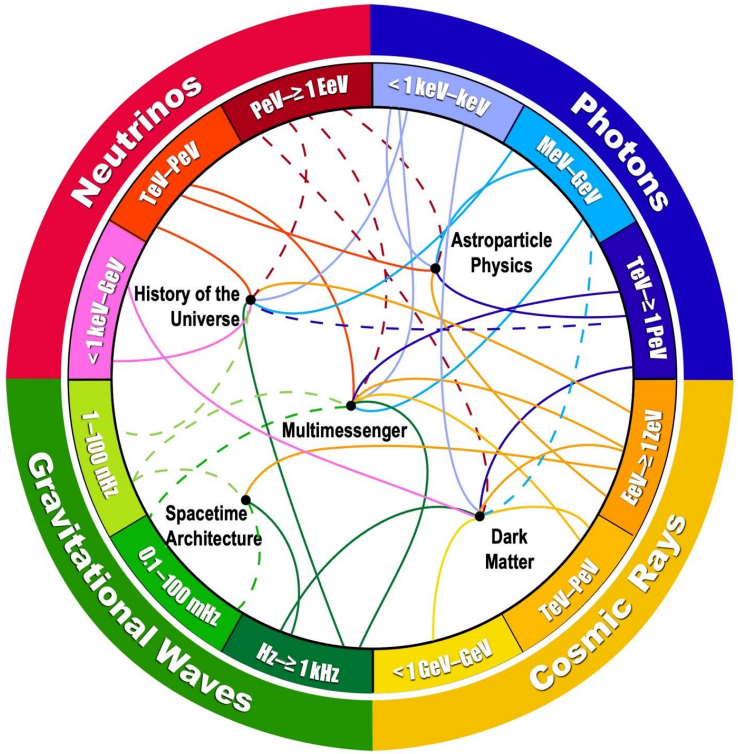
137 Letters of Intent; 12 white papers

Link to CF7 Report:
https://www.dropbox.com/s/7aaxxlmtcjvxyqb/CF7-report.pdf?dl=0

Feedback form:
https://forms.gle/kKuWWPgRaohQ8YqN7

Five main topical areas drived by big science questions with cosmic probes over the next decade:

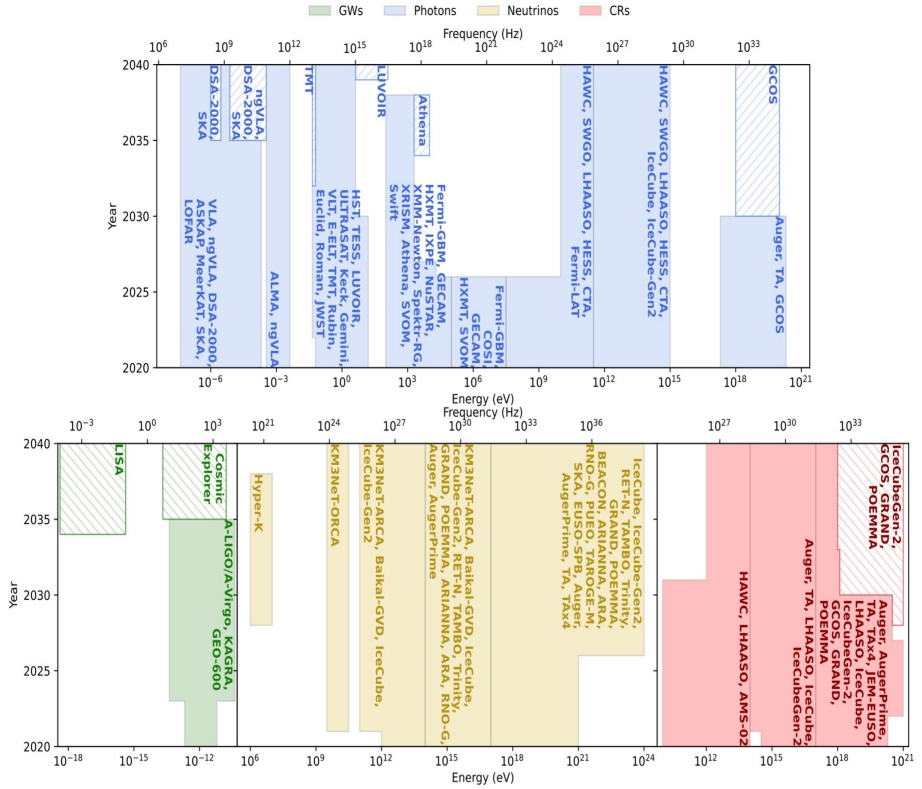
- History of Universe and Cosmology
- Cosmic Probes of Dark Matter
- Astroparticle Physics
- Multimessenger Synergies in Particle Astrophysics
- Architecture of Spacetime



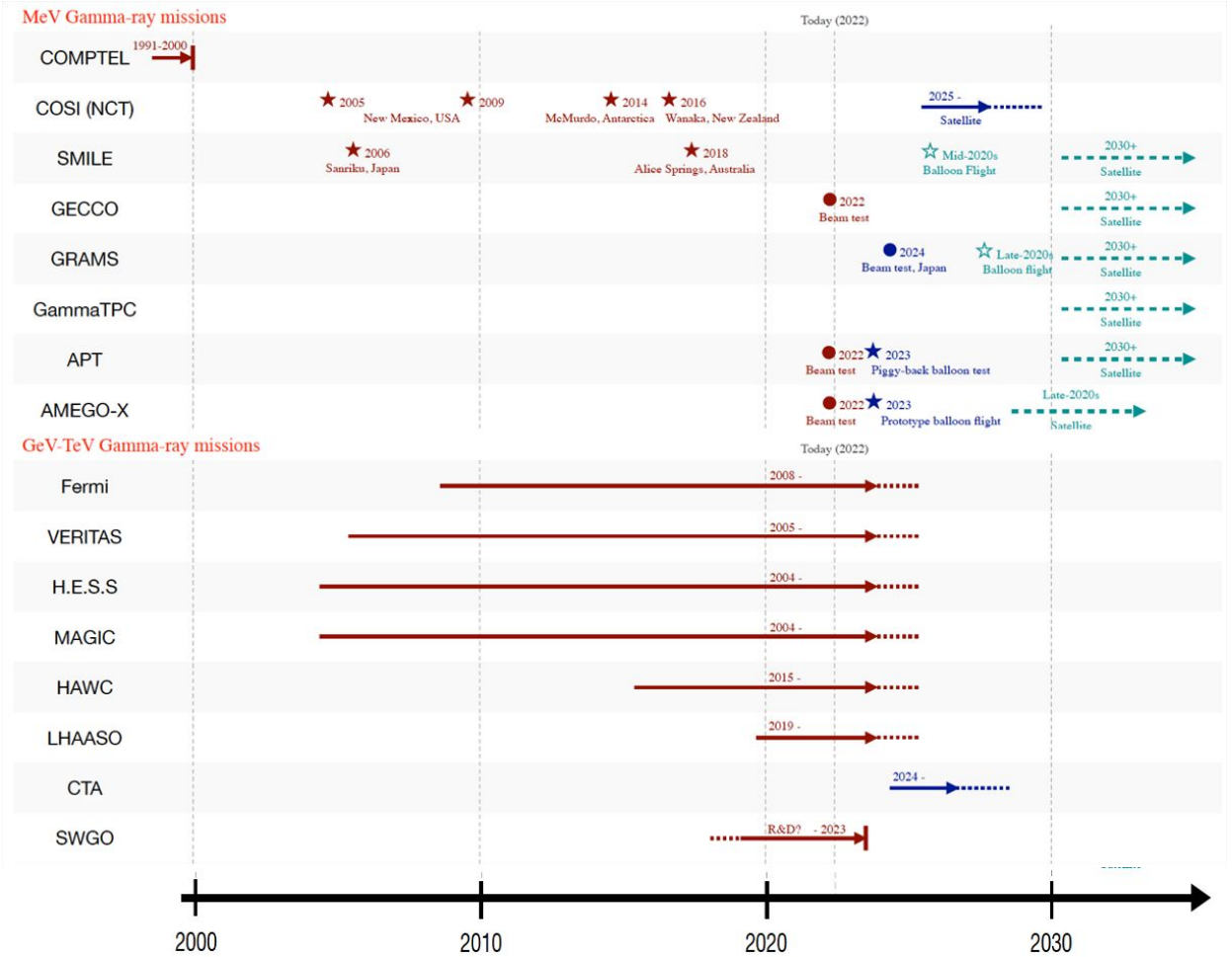
Solid curve: current existing facilities
Dashed curve: future experiments

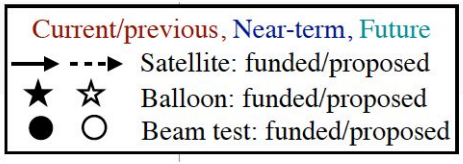
Multimessenger Synergies in Particle Astrophysics

- **Sources of Cosmic Particles**
- **Extreme-energy particle acceleration and interaction**
- **Diffuse backgrounds:** gamma-ray, supernova neutrino, astrophysical diffuse neutrino, cosmogenic neutrino backgrounds, and Galactic diffuse emission
- **Galactic TeVatrons and PeVatrons**
- **Production of heavy elements**



Gamma-Ray Instrumentation Roadmap

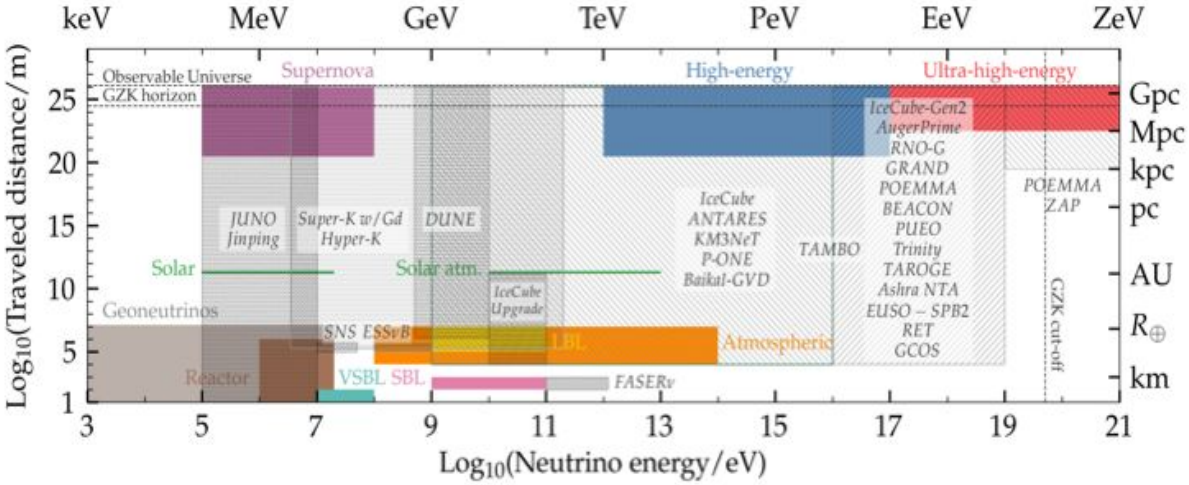




Instrumentation Roadmap

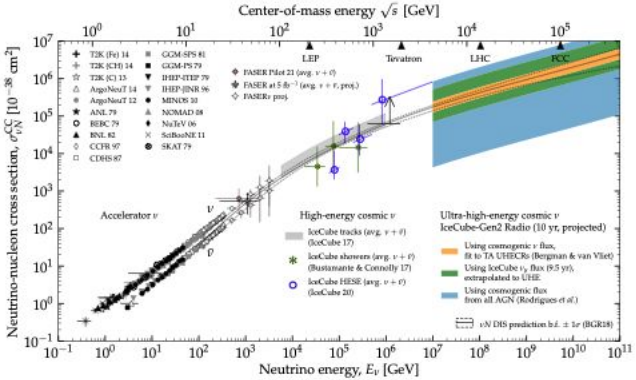
Experiment	Feature	Cosmic Ray Science	Timeline
Pierre Auger Observatory	Hybrid array: fluorescence, surface e/μ + radio, 3000 km^2	Hadronic interactions, search for BSM, UHECR source populations, $\sigma_{\text{p-Air}}$	AugerPrime upgrade
Telescope Array (TA)	Hybrid array: fluorescence, surface scintillators, up to 3000 km^2	UHECR source populations, $\sigma_{\text{p-Air}}$	TAx4 upgrade
IceCube / IceCube-Gen2	Hybrid array: surface + deep, up to 6 km^2	Hadronic interactions, prompt decays	Upgrade + surface enhancement; IceCube-Gen2 deployment; IceCube-Gen2 operation
GRAND	Radio array for inclined events, up to 200,000 km^2	UHECR sources via huge exposure, search for ZeV particles, $\sigma_{\text{p-Air}}$	GRANDProto 300; GRAND 10k; GRAND 200k multiple sites, step by step
POEMMA	Space fluorescence and Cherenkov detector	UHECR sources via huge exposure, search for ZeV particles, $\sigma_{\text{p-Air}}$	EUSO program; POEMMA
GCOS	Hybrid array with $X_{\max}$ + e/μ over 40,000 km^2	UHECR sources via event-by-event rigidity, forward particle physics, search for BSM, $\sigma_{\text{p-Air}}$	GCOS R&D + first site; GCOS further sites

2025 2030 2035 2040

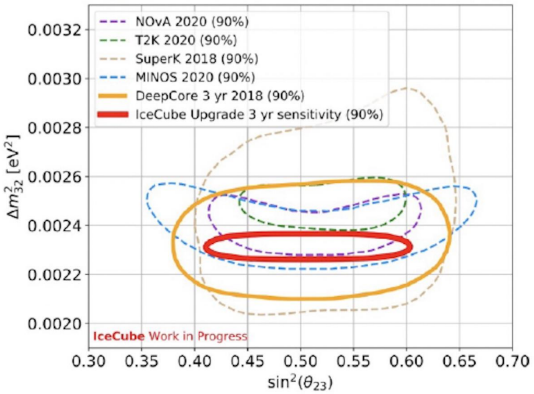


Astroparticle Physics

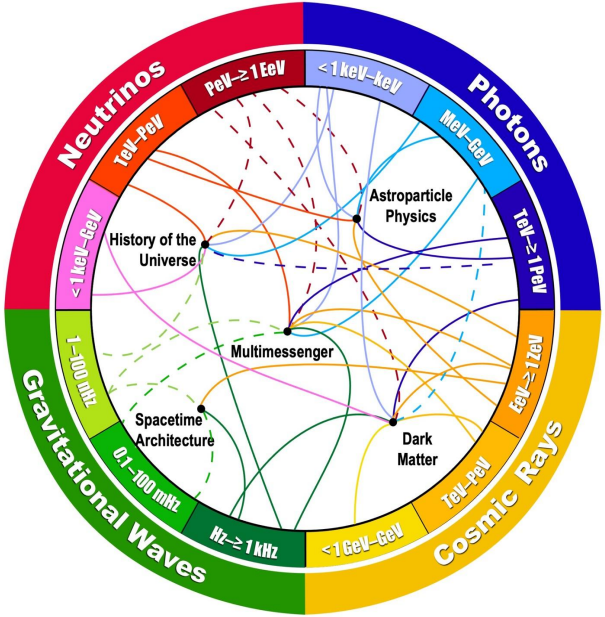
- **Standard Model particles and their interactions**
- **Beyond-Standard-Model (BSM) neutrino physics:** BSM neutrino interaction with DM, sterile neutrinos, secret neutrino interactions, neutrino flavors
- **Muon puzzle of UHECRs**
- **Nature of matter in neutron star interiors**
- **Test of Lorentz and CPT invariance**
- **Exotic particles in QED domain**



Ackermann et al., *HE and UHE neutrino whitepaper* 2203.08096



Updated from IceCube Coll. 1908.09441

Conclusion:
Great Opportunities for Discoveries

- Several Science Objectives from Multi-Messenger Probes (EM, UHECR, GW, nu)
- Cosmic Probes of Dark Matter: Particle, wave, or modified gravity
- Cosmology: probes of H_0, dark energy, …
- Astroparticle Physics
- Tests of the Structure of Spacetime