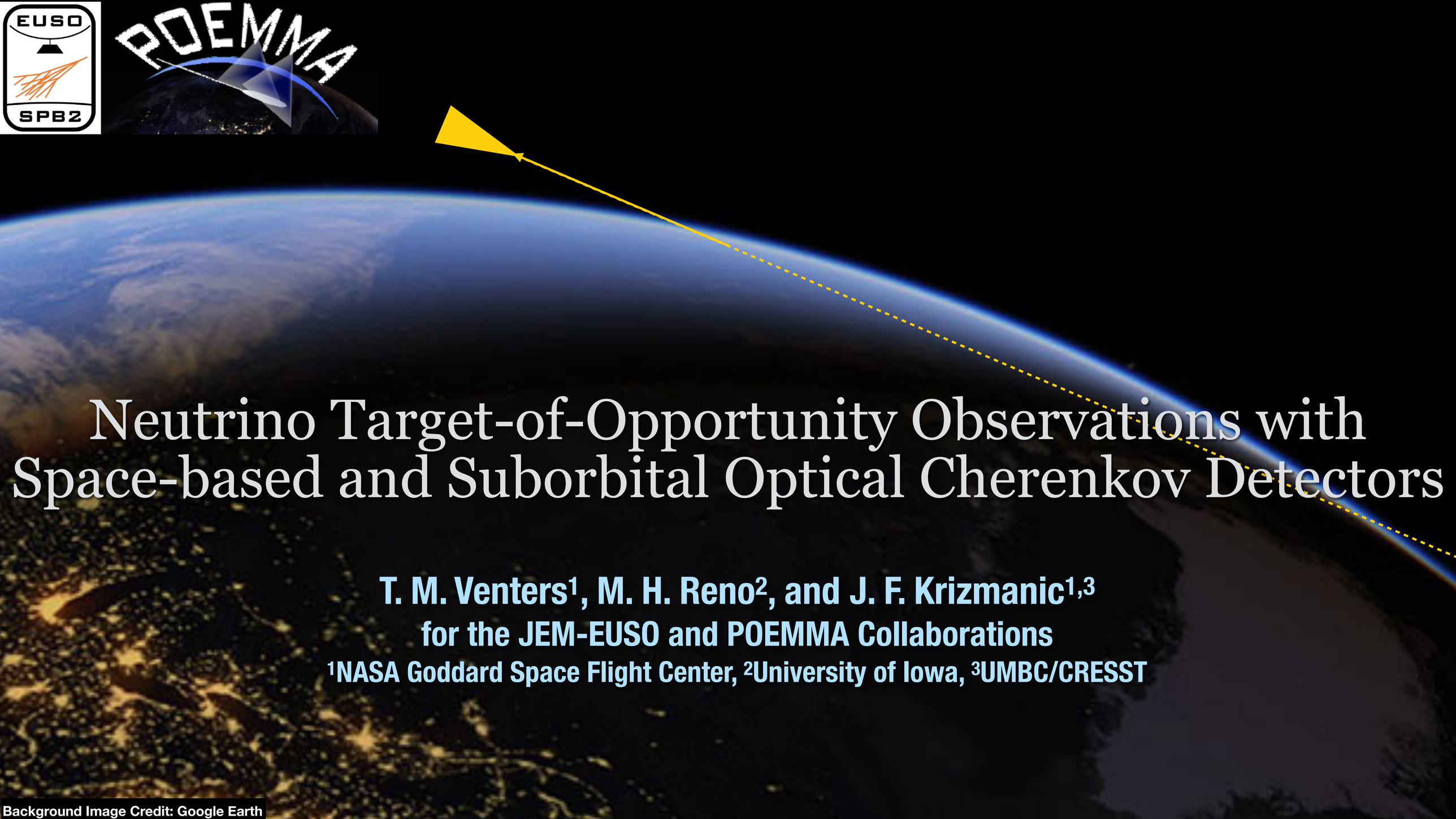


Neutrino Target-of-Opportunity Observations with Space-based and Suborbital Optical Cherenkov Detectors

T. M. Venters[1], M. H. Reno[2], and J. F. Krizmanic[1,3]
for the JEM-EUSO and POEMMA Collaborations
[1]NASA Goddard Space Flight Center, [2]University of Iowa, [3]UMBC/CRESST

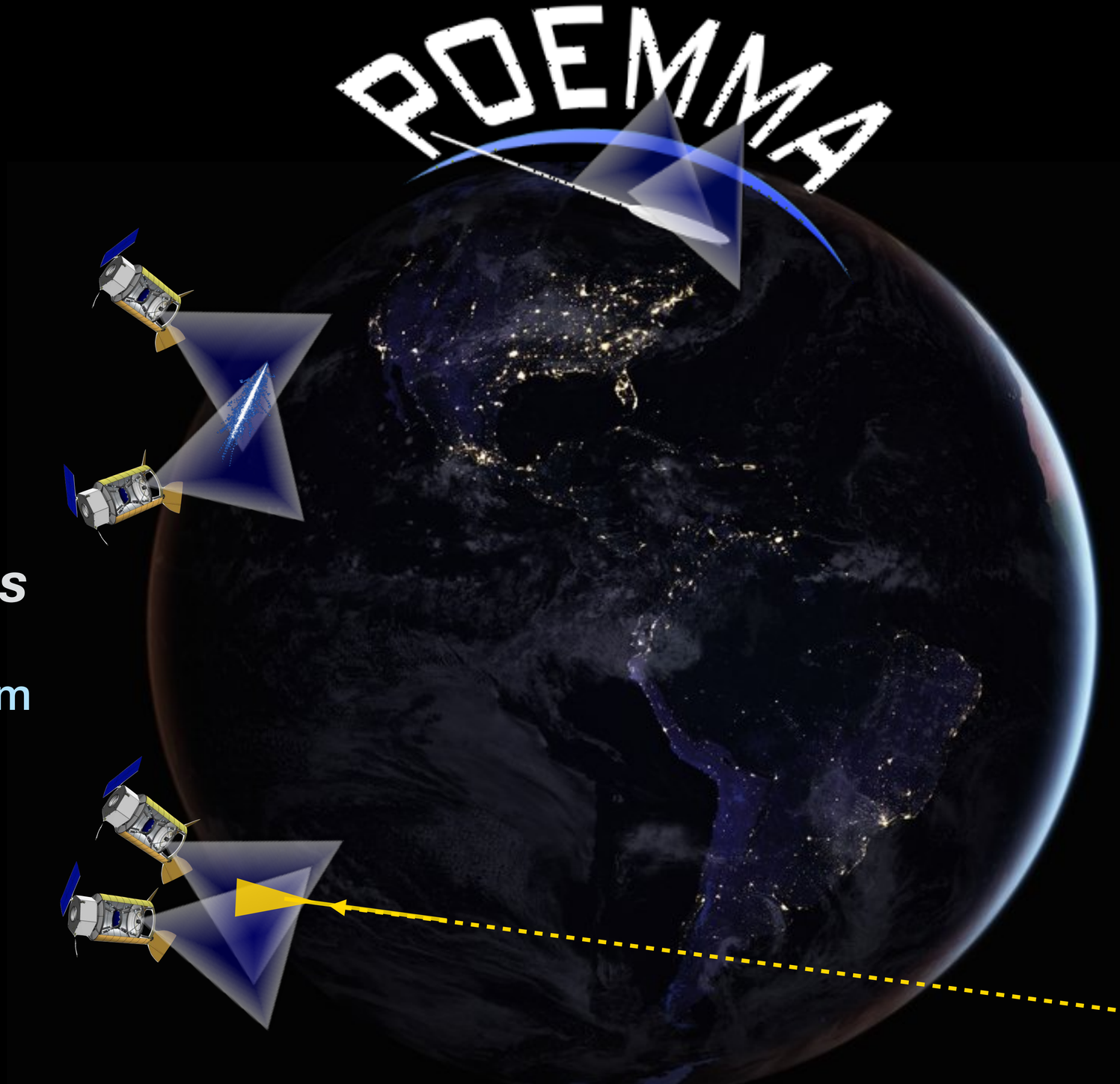
Background Image Credit: Google Earth

Probe of Extreme Multi-Messenger Astrophysics

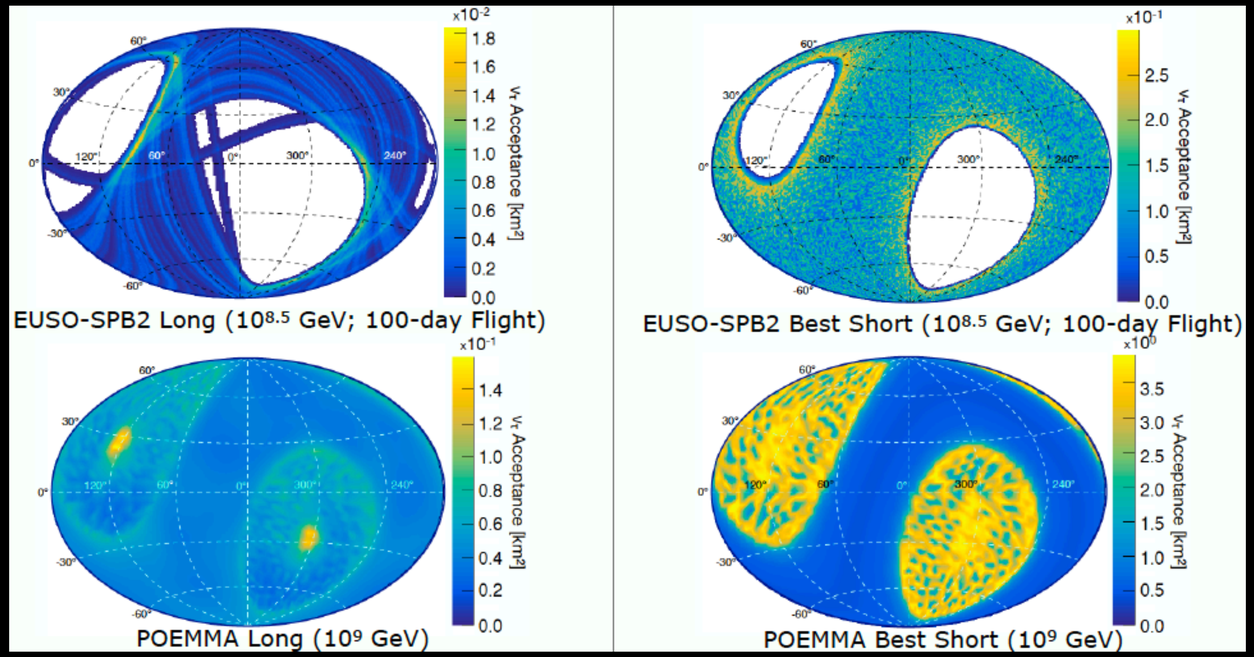
A NASA probe-class mission to perform transformational measurements of UHECRs and cosmic neutrinos.

Select Specifications:

- EAS detection via fluorescence and Cherenkov
- Mission Lifetime: 3 years (5 year goal)
- Orbit: 525 km, 28.5° inclination, T_{orb} = 95 mins.
- Field of view: 30° × 9°
- Slew Rate: 90° in 8 mins.
- Slew + Orbit + FoV ➜ ~ 21%/37% of sky accessible in 500 s/1000 s

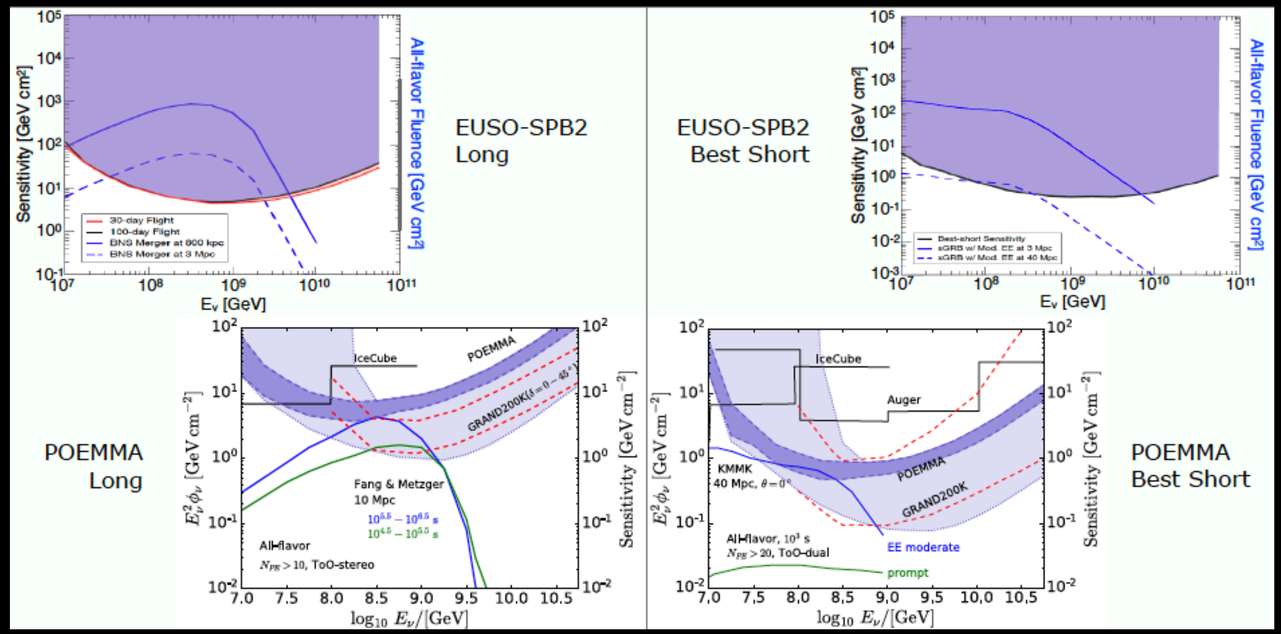


Sun and Moon Effects



Sky Coverage

Transient Sensitivity



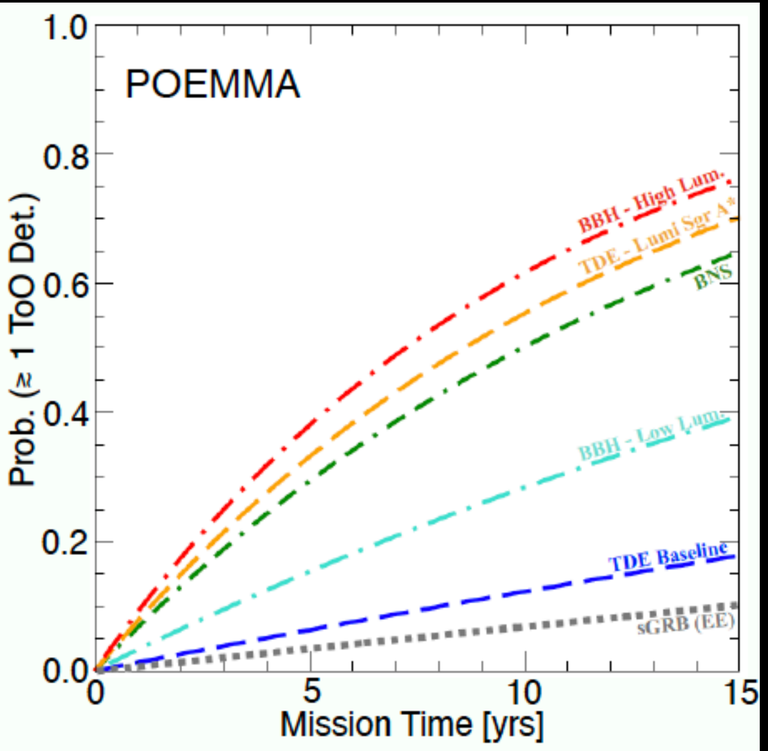
Prospects for ToO Detection

Source Class	EUSO-SPB2 ν Horizon Distance	POEMMA ν Horizon Distance	Model Reference
TDE $M_{\rm SMBH} = 5 \times 10^5 M_\odot$	9 Mpc	128 Mpc	Lunardini & Winter (2017)
TDE Base Scenario	4.5 Mpc	69 Mpc	Lunardini & Winter (2017)
BBH merger – Low Fluence	6 Mpc	43 Mpc	Kotera & Silk (2016)
BBH merger – High Fluence	19 Mpc	137 Mpc	Kotera & Silk (2016)
BNS merger	2.3 Mpc	16 Mpc	Fang & Metzger (2017)
sGRB w/ Mod. Extended Emission	25 Mpc	90 Mpc	Kimura et al. (2017)

Horizon Distances for Detecting at Least 1 Neutrino

⊗

Cosmol. Event Rate



Poisson Detection Probabilities Over Mission Lifetime

Neutrino Target-of-Opportunity Observations with Space-based and Suborbital Optical Cherenkov Detectors

T. M. Venters[1], M. H. Reno[2], J. F. Krizmanic[1,3] on behalf of the JEM-EUSO and POEMMA Collaborations

Background

- Many candidate astrophysical neutrino sources associated with transient events
- Space and suborbital Cherenkov expts. detect up-going ν_τ air showers:
  - ν_τ enters Earth → charged current interaction → τ emerges from ground → τ decays → air shower → Cherenkov signal
- In space: T_{obs} (~ 95mins.) + slewing → Access to large parts of sky
  - ➢ *Space missions uniquely suited for transient follow-up*
- POEMMA is a proposed space-based mission featuring an optical Cherenkov camera for detecting very-high energy neutrinos.
- EUSO-SPB2 is a balloon-borne experiment and is a pathfinder mission for POEMMA.
  - Launch expected in Spring 2023 from Wanaka, New Zealand.

Method

Scenarios

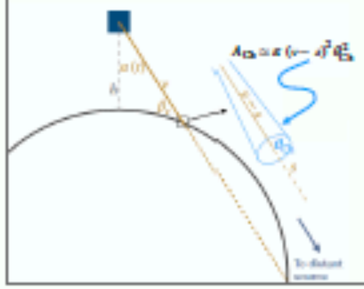
Long Burst

- Event duration ≥ 1 day
- POEMMA satellite separation ~ 50 km (lower E threshold)
- duty cycle (ℓ) determined by Sun and Moon constraints

Short Burst

- Event duration ~ 1000 sec.
- POEMMA satellite separation ~ 300 km (higher E threshold)
  - Satellites observe indep.
- Ignoring Sun and Moon ($\zeta = 1$)
- Assume best-case scenario:
  - Source dips below limb at ξ_0

Calculations



Instantaneous Acceptance:

$$A\left(\alpha(t), E_\nu\right) \simeq \int d\mathrm{P}_{\mathrm{obs}}\left(E_\nu, \beta_\tau, r\right) A_{\mathrm{CS}}(x)$$

Average over Observ. Time:

$$\left\langle A\left(E_\nu\right)\right\rangle_{T_{\mathrm{obs}}} = \frac{1}{T_{\mathrm{obs}}} \int_{t_0}^{t_0+T_{\mathrm{obs}}} A\left(\alpha(t), E_\nu\right) dt$$

All-flavor Sensitivity:

$$\frac{2.44}{\ln(10)} \times \frac{(N_\sigma = 3)\, E_\nu}{f\left\langle A\left(E_\nu\right)\right\rangle_{T_{\mathrm{obs}}}}$$

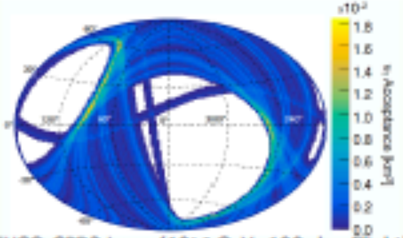
Number Events:

$$N_{ev} = \int_{\Delta E_\nu} \phi_\nu\left(E_\nu, z\right) \left\langle A\left(E_\nu\right)\right\rangle_{T_{\mathrm{obs}}} dE_\nu$$

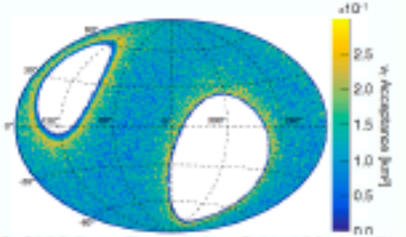
$\phi_\nu\left(E_\nu, z\right)$ = at-Earth ν fluence

Results

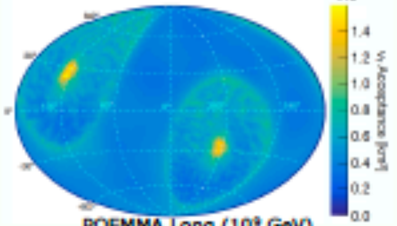
Acceptance Sky Plots



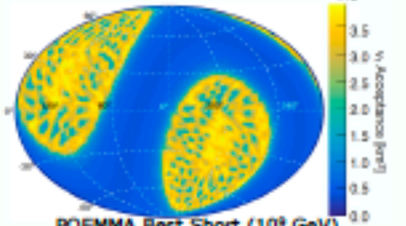
EUSO-SPB2 Long ($10^{8.5}$ GeV; 100-day Flight)



EUSO-SPB2 Best Short ($10^{8.5}$ GeV; 100-day Flight)

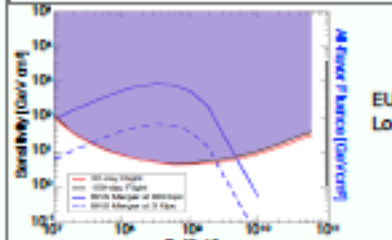


POEMMA Long (10^9 GeV)

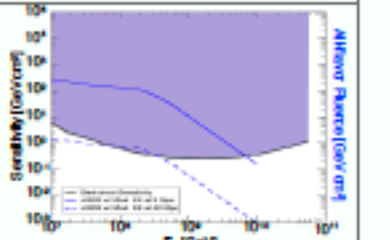


POEMMA Best Short (10^9 GeV)

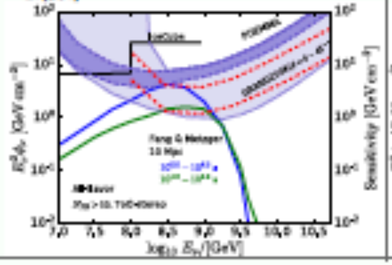
Transient Sensitivity



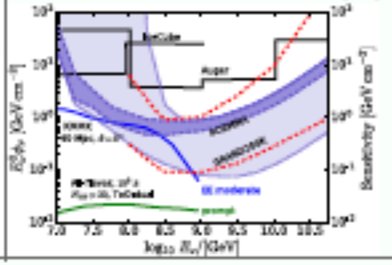
EUSO-SPB2 Long



EUSO-SPB2 Best Short



POEMMA Long



POEMMA Best Short

Results (cont.)

Prospects for ToO Detection

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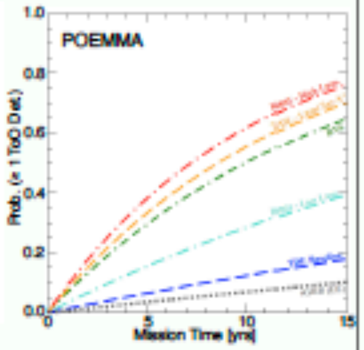
BNS merger	1.1 Mpc	16 Mpc	Fang & Metzger (2017)
sGRB w/ Mod. Extended Emission	25 Mpc	56 Mpc	Kimura et al. (2017)



Horizon Distances for Detecting at Least 1 Neutrino ⊗ **Cosmol. Event Rate** → **Poisson Detection Probabilities Over Mission Lifetime**

Conclusions

- Most promising candidate astrophysical neutrino sources are tidal disruption events (TDEs), binary neutron star (BNS) mergers, and binary black hole (BBH) mergers.
- Both POEMMA and EUSO-SPB2 will be able to detect these sources out to well beyond the Galaxy.
- Prospects for detecting a ToO are promising for POEMMA.
- ToO studies to be included in vSpaceSim neutrino simulation package.

References

[1] The POEMMA Collab., 2021, JCAP, 06, 007
[2] Eser, J., Olinto, A. V., & Wiencke, L., et al., 2021, PoS (ICRC21), 404
[3] Reno, M. H., Venters, T. M., & Krizmanic, J. F., et al., 2021, PoS (ICRC21), 1201
[4] Krizmanic, J. F., et al., 2021, PoS (ICRC21), 1205
[5] Venters, T. M., et al., 2020, PRD, 102, 123013
[6] Reno, M. H., Venters, T. M., & Krizmanic, J. F., 2019, 100, 063010

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