

TANGO

Time-domain All-sky Nuclear Gamma-ray Observatory

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Optimize Discovery

Max. Flux Sensitivity
Max. Sky Coverage
Reduce Cost-Complexity Barriers

Leverage Moon

*Decades of planetary
orbital geochemistry*

Foundational Capabilities

Multi-scale Time-domain Astrophysics
Continuous All-sky Monitoring
Deep MeV Survey
Nuclear Light Curves
Precise Source Localization



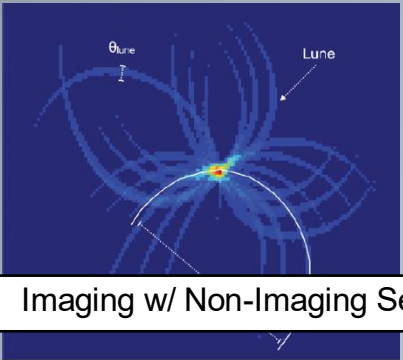
Ex Luna, Scientia!

Energy Range	0.1-20 MeV
Energy Resolution	$\lesssim 10\%$ (FWHM, 0.662 MeV)
Src. Localization	$\lesssim 0.2^\circ$, energy independent Scalable
Data Product (primary)	Time-resolved Spectra
Spectrum Acq. Cadence	Scalable 10 sec (nominal, TBC)
Spectrum Size	512 channels (nominal)
Instrument	Large-area GRS array
No. of GRS modules	Scalable
Effective Area	Scalable
Continuum Sensitivity	Scalable
Line Sensitivity	Scalable
Sky Coverage per Orbit	$\sim 4\pi$ sr
Duty Cycle	$\geq 95\%$
Lunar Orbit Altitude	Scalable 1000 km (nominal, TBC)
Nadir Pointing	
No Slewing No kinematic event reconstruction	

The Moon serves as an occulting disk to repeatedly eclipse astrophysical sources. Temporal modulation, unique to each location on the sky, is encoded within a time-series of detector counts as sources rise **1** and set **2** over the limb of the Moon.

Time-resolved spectra
(cadence, Δt)

All info to:
Detect
Localize
Characterize
Monitor

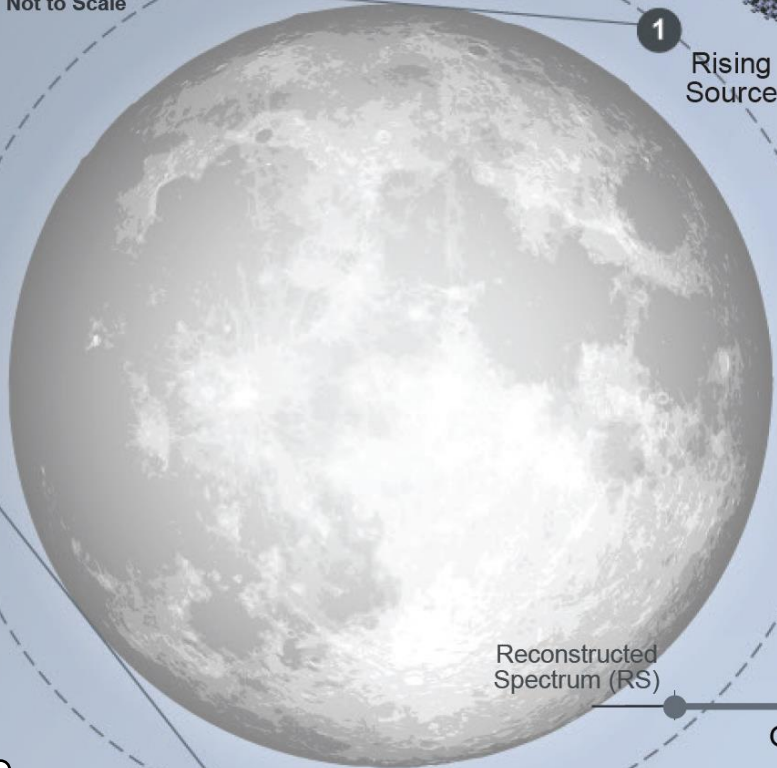


Imaging w/ Non-Imaging Sensors

Not to Scale



1
Rising Source



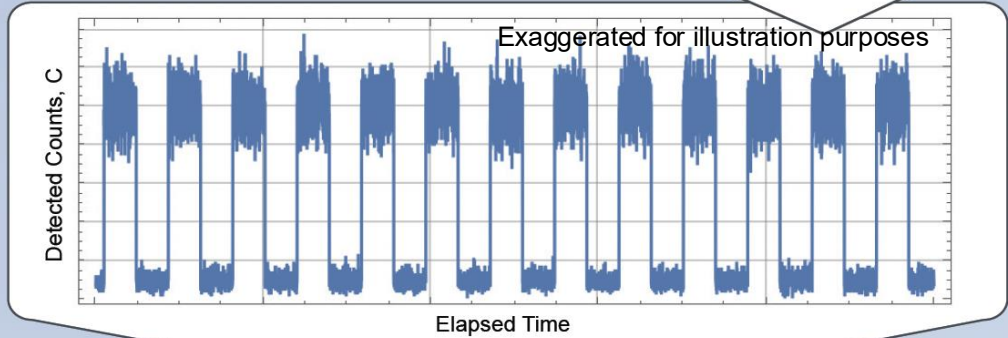
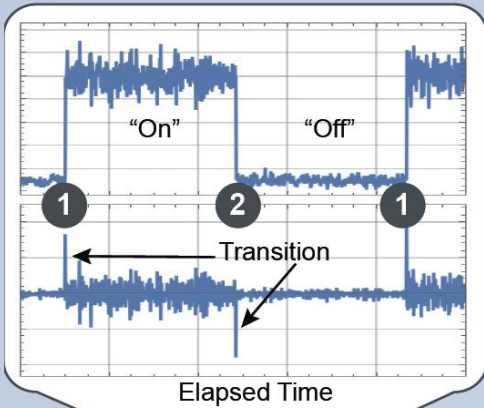
Reconstructed Spectrum (RS)

2
Setting Source

Lunar eclipses produce “on” (source+background) and “off” (background) measurement intervals, each consisting of hundreds of independent measurements. A well-established statistical framework isolates astrophysical signatures

Transition times are unique
(src location & ephemerides)

Statistical analysis: transition ensembles
(exact Clopper-Pearson CI)



RS
OP 1

RS each OP

OP 2

RS
OP 3

RS
OP 4

RS
OP 5

Light curves spanning Observing Periods (OP)

The Case for the Moon

Sensitivity Gains via Stable Well-characterized Background Environment

$$\phi_\gamma \propto \sqrt{\frac{\phi_B}{\varepsilon A_{\text{grs}} \Delta t}} \rightarrow \sqrt{\frac{\phi_B}{\varepsilon A_{\text{grs}} \Delta t N_{\text{grs}}}} \rightarrow \sqrt{\frac{\phi_B}{\varepsilon A_{\text{grs}} \Delta t N_{\text{grs}} N_{\text{occ}} N_{\text{sc}}}}$$

Single transition Single detector Single transition Multiple detectors Multiple transitions Multiple detectors

Reduced Background Intensity (Φ_B)

+

Long Variability Timescales
(solar, weeks to months)

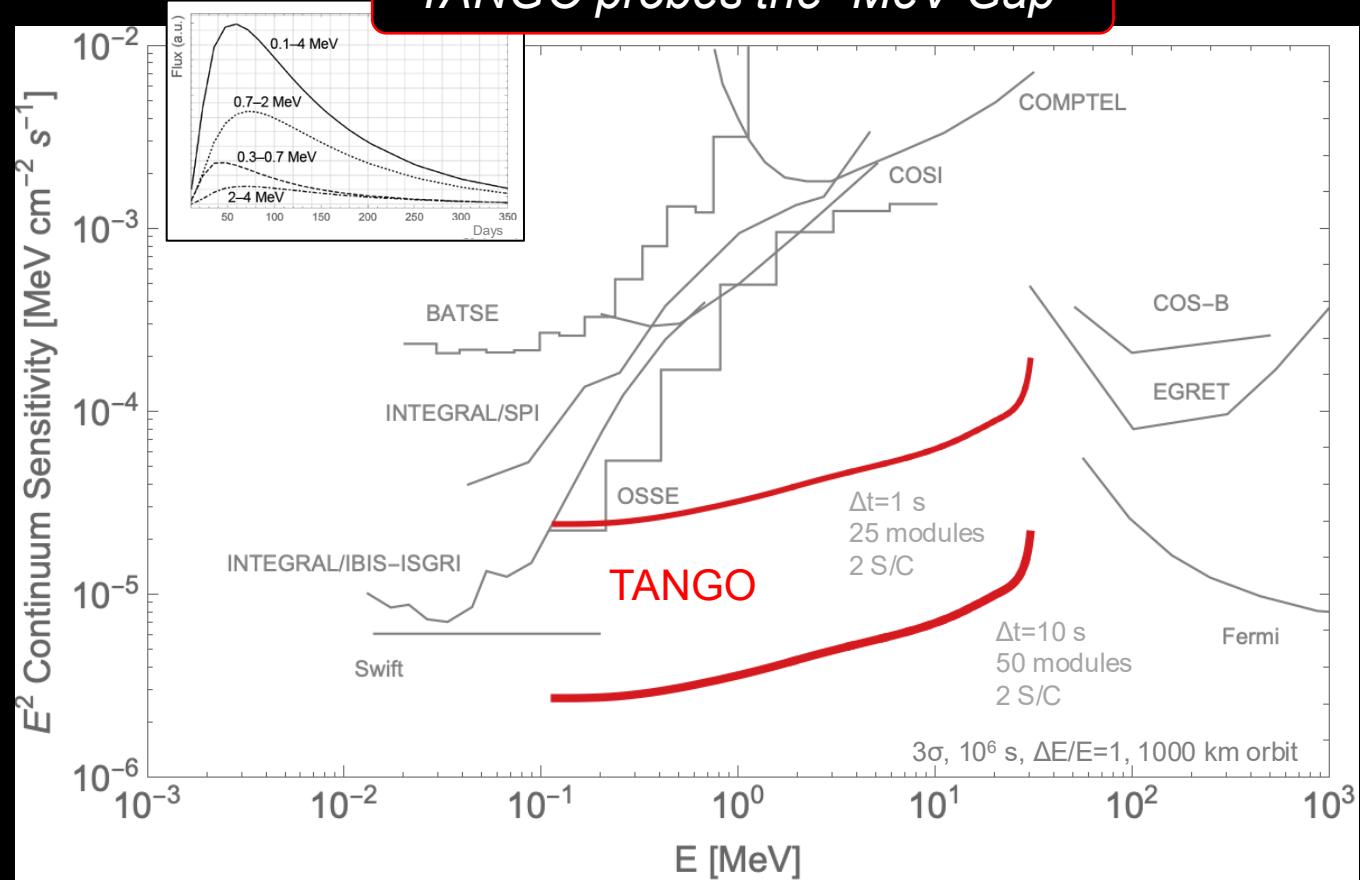
Mitigation of (multi-orbit) systematic effects

=

Transition ensembles

Maximize On-Src Time ($\Delta t N_{\text{occ}} N_{\text{sc}}$)

TANGO probes the “MeV Gap”

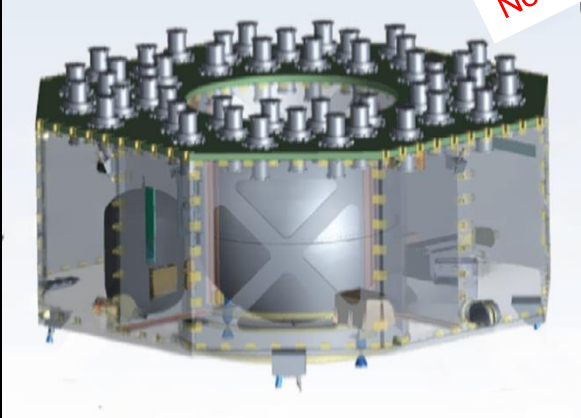
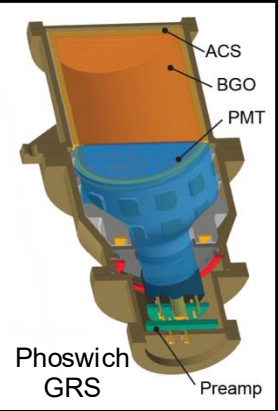


Adapted from Fujiwara et al. (2025)
Johnson et al. (1993)

Implementation

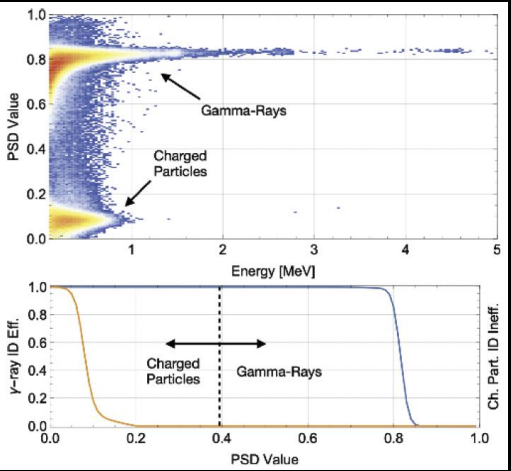
Maximize Detector Area ($\epsilon A_{grs} N_{grs}$)

→ **Non-imaging** (large area) gamma-ray spectrometer



Components: TRL 9
System: TRL 4

Pulse-shape
discrimination-based
Anti-Coincidence
System (ACS)



**Big Array for
Gamma-ray Energy Logging
(BAGEL)**

BGO: highest photopeak eff.
($\rho=7.16 \text{ g/cm}^2$)
 $\sigma E/E \sim 10\% @ 0.662 \text{ MeV}$

No kinematic event reconstruction

Multi-S/C beneficial to imaging

→ **TANGO Intra-lunar Network (GRBs)**
Standalone or in conjunction with IPN/GCN

→ **ARTEMIS & Moon Base**
CN-U-707 L Helio from lunar orbit
CN-U-718 L Real-time space weather monitoring
HS-01 LM Weather environment at Moon
CN-U-102 L Space weather early warning
AS-01 LM Crew operations safety (space weather)
LI-09 L Monitoring & situational awareness at Moon

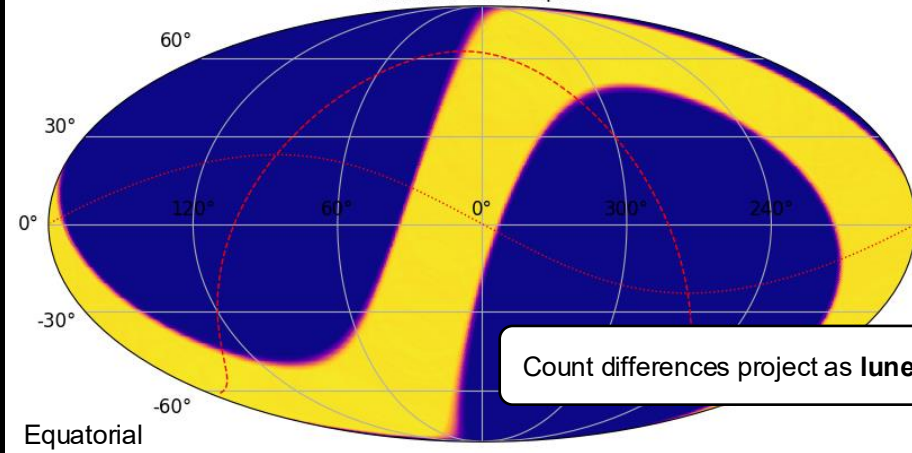
Moon to Mars Arch. Def. Doc., ESDMD-001, Rev B



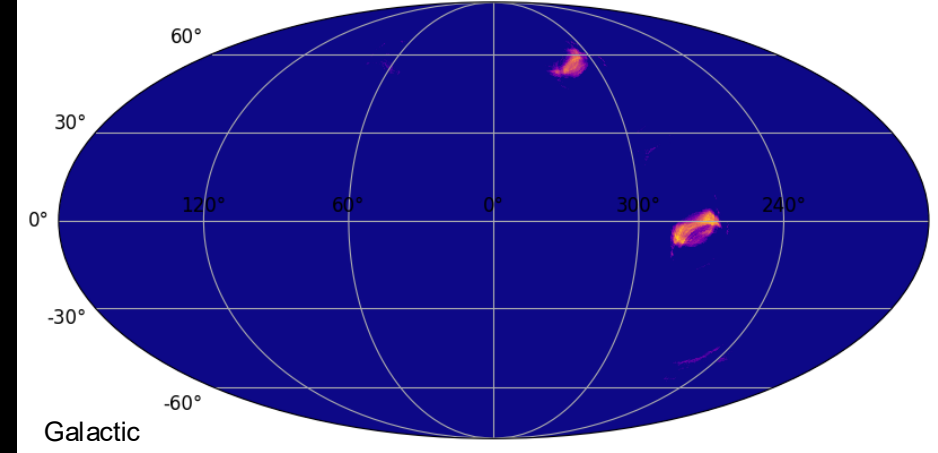
Imaging

In-situ Validation
Lunar Prospector GRS

Sky Survey (LP)



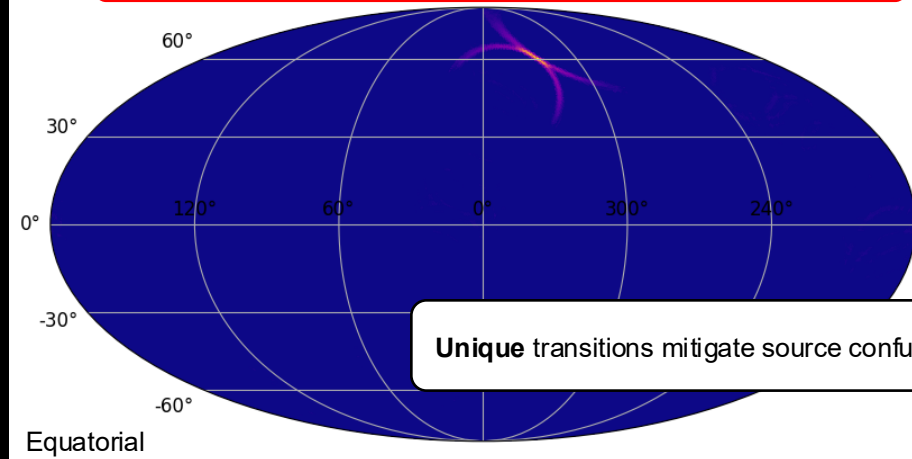
Detections (LP)



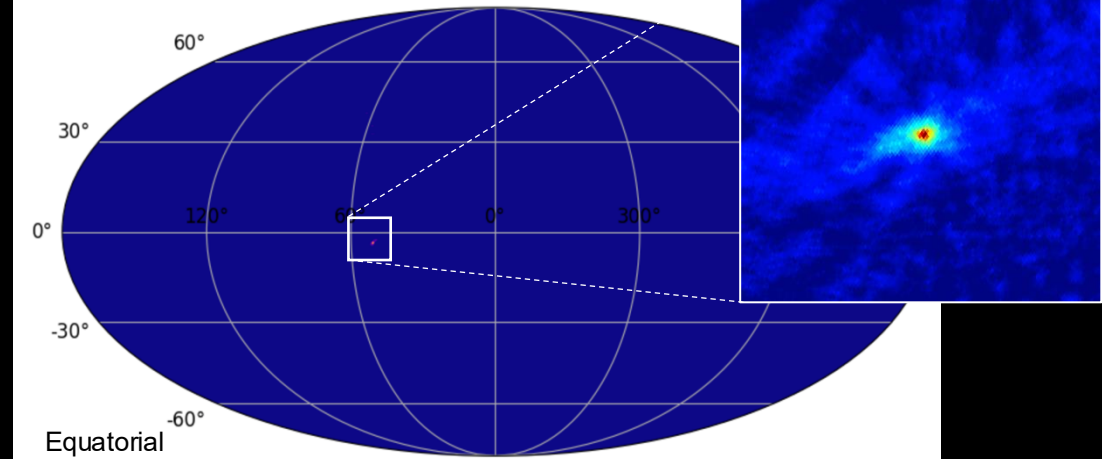
Miller & Peplowski (2026), in prep

Sources @
locus of lunes

Modeled Localization (1 S/C, no precession)



Modeled Localization (2 S/C)



$\lesssim 0.2^\circ$

Independent of energy & location



TANGO is Scalable

Implementation

2-4 S/C (Probe-class)
Single Instrument Payload (BAGEL)
✓ In-situ Concept Validation

Drivers & Dev. Plan

Open Issues Dominated by
Implementation Details
NOT Tech. Dev.



**Optimization
of
Implementation Parameters**

BAGEL GRS maturation

Custom vs. Commodity S/C

High-resolution Spectroscopy

Top-level Concept Implementation Parameters

h	Orbit altitude → Φ_B , N_{occ}
Δt	Spectrum acquisition cadence
N_{grs}	GRS modules per S/C
N_{sc}	No. of S/C

Performance: Slide 1 & 3 (scalable)
Components: TRL 9
System: TRL 4

Composite GRS encapsulation
Enhanced pulse processing (DPU)
Calibration & intra-GRS systematics mitigation

- Beneficial lunar environment
- Planetary mission heritage
- Simple concept of operations

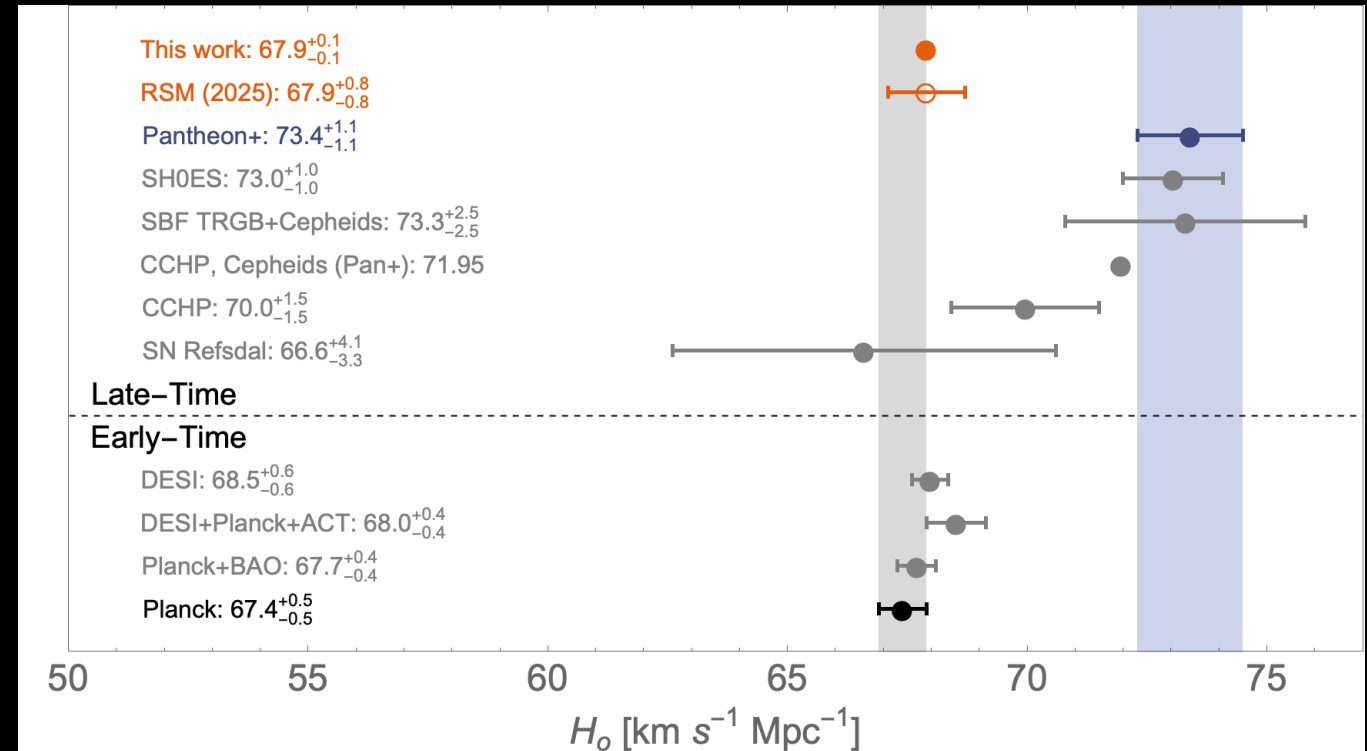
- Performance-SWaP-Cost Trade Study
- SWaP mitigation & scaling
- Independent mission?

Connection to High-Profile Science: Hubble Tension

MeV γ -rays have a critical role w.r.t. key open questions in supernova cosmology



- Thermonuclear Diversity $\Rightarrow$ Hubble Tension
 - Diverse Evolutionary Pathways
 - Progenitor Age Effect
 - Pantheon+
- $>5\sigma$ evidence for flat $w_0 w_a$ CDM w/ diversity mitigation
- Diversity is manifest, progenitor models are not
- Requirement: SNe Ia (γ -ray) population studies
- Post-explosion SNe Ia (broad-band) γ -ray light curves can discriminate models $\rightarrow$ **TANGO**



RSM (2025), PRD 111 L081305
RSM (2026), ApJ, in review