DOE Genesis Mission — Phase I Project · FOCUS AREA 14-C · DE-FOA-0003612

Learning Beyond Threshold

AI-Driven Signal Extraction for Rare-Event Searches

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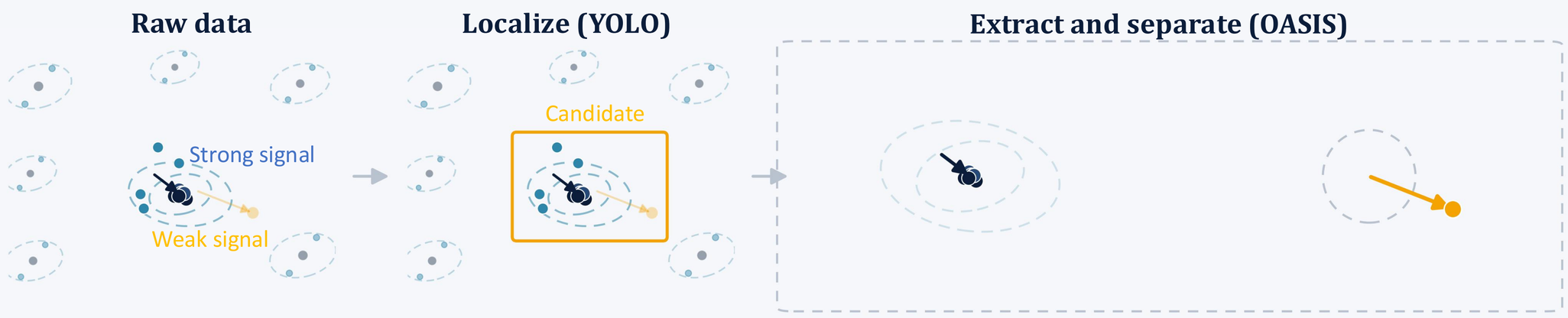
One Shared Challenge, 40 orders of magnitude in scale

Across nuclear, atomic, and astrophysical scales, the most valuable signal is often the faintest one — hidden beneath a far brighter background, an overlapping structure, or dominant noise. This project aims to use a generalizable two-stage AI workflow that recovers weak signals wherever they occur, from a single nucleus to a galaxy-scale dark matter halo.

Localize, Then Extract: A Two-Stage AI Workflow

Stage 1 localizes the candidate region containing a rare event, using an AI object detector (YOLO) or a conventional trigger / coincidence tag.
Stage 2 applies OASIS, an overlap-aware segmentation-regression network with a novel loss function, to decompose that region into its physically meaningful components or their representations — separating the faint signal from the brighter background at the pixel or waveform-sample level.



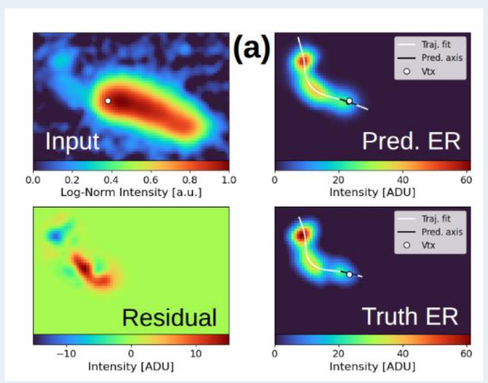
Migdal Effect — Atomic Scale

MIGDAL / Rutherford Appleton Lab · light dark-matter searches

GOALS

- Localize faint electron-recoil (ER) tracks overlapping brighter nuclear recoils with YOLO
- Apply OASIS to real mixed ^{55}Fe + D-D generator data to reconstruct pure ER spectra
- Benchmark vs. threshold/masking: peak position within 15%, resolution within 50%

Signal: faint electron-recoil (ER) track
Background: orders-of-magnitude brighter nuclear-recoil (NR), noise within the image



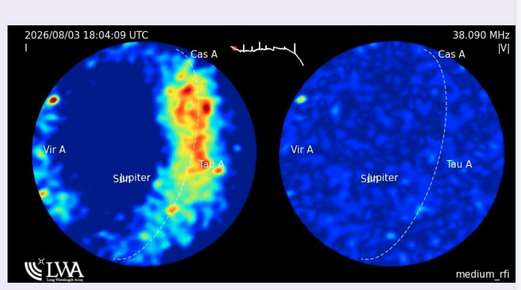
LWA Transients — Stellar / Interstellar Scale

Long Wavelength Array · time-domain radio astronomy

GOALS

- Adapt YOLO-style localization across space, time, frequency, and polarization axes
- Identify known and new transient classes across ~1 PB of archival LWA data
- Reject corrupted images while preserving genuine rare transients

Signal: a genuine astrophysical radio transient
Background: Ionospheric scintillation and RF interference



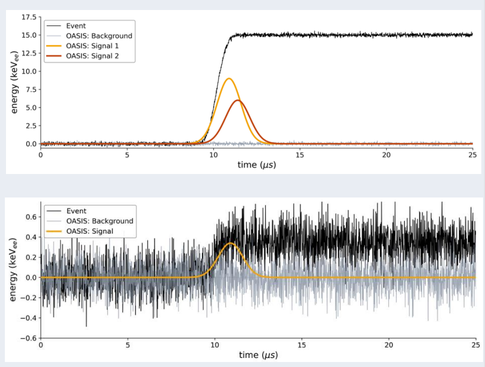
HPGe Waveforms — Nuclear Scale

Los Alamos National Laboratory · COHERENT neutrino scattering and LEGEND double beta-decay

GOALS

- Generalize OASIS from 2-D images to 1-D, sample-wise waveform decomposition
- Separate weak physical pulses from baseline, electronic, and readout noise, or a 2nd physics pulses
- Application to existing experimental data from MAJORANA, LEGEND-200 and LEGEND-1000

Signal: charge pulse within baseline noise
Background: baseline electronic, readout noise, 2nd radiative events



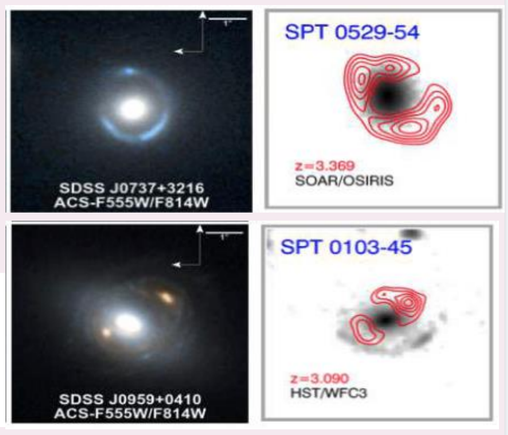
Strong Lensing — Galactic / Cosmological Scale

Rubin Observatory era · galactic & dark-matter substructure

GOALS

- Investigate if YOLO could be an alternative to identify strongly lensed regions in wide-field imaging
- Apply OASIS to deblend lensed-source/halo signal from bright foreground lens light
- Characterize halo-detection efficiency against lens-fitting baselines

Signal: lensed-source emission / halo perturbation
Background: bright foreground lens-galaxy light



Key References:

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OASIS J. Schueler et al 2026 Mach. Learn.: Sci. Technol. 7 035046