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Onboard AI: Enhancing High-Energy Space Missions with Machine Learning

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Artificial Intelligence (AI) and Machine Learning (ML) are revolutionizing satellite and CubeSat operations by enabling real-time, onboard data processing. This paradigm shift minimizes the need for extensive data transmission to ground stations, optimizes satellite performance, and enhances scientific discovery. By processing data directly in space, satellites can rapidly identify and respond to transient astrophysical events, triggering real-time science alerts crucial for multi-messenger astronomy. This increased autonomy not only boosts mission efficiency but also reduces reliance on continuous ground communication. Advances in ML, coupled with hardware acceleration technologies such as GPUs, FPGAs, and Edge Computing devices, are making these capabilities a reality. Deploying ML models on low-power, embedded computing platforms allows complex analyses to be performed in space, improving both the responsiveness and adaptability of space-based observatories. In this work, we present ML models optimized for onboard signal analysis from scintillator detectors, addressing key challenges such as pile-up and waveform saturation to enhance energy resolution. To ensure efficient deployment on Edge Computing devices, we explore model optimization techniques, including quantization and pruning, to reduce computational overhead while maintaining accuracy. We believe that ML will play a transformative role in gamma-ray data analysis. To unlock its full potential, we are actively investigating novel approaches to integrate AI-driven methodologies into future high-energy astrophysics missions.

Presenter: Dr PARMIGGIANI, Nicolo' (Istituto Nazionale di Astrofisica (INAF))

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