



Contribution ID: 39

Type: Fractional talk

Machine-directed gravitational-wave counterpart discovery

Friday, December 1, 2023 3:46 PM (7 minutes)

Joint observations in electromagnetic and gravitational waves shed light on the physics of objects and surrounding environments with extreme gravity that are otherwise unreachable via siloed observations in each messenger. However, such detections remain challenging due to the rapid and faint nature of counterparts. Protocols for discovery and inference still rely on human experts manually inspecting survey alert streams and intuiting optimal usage of limited follow-up resources. Strategizing an optimal follow-up program requires adaptive sequential decision-making given evolving light curve data that (i) maximizes a global objective despite incomplete information and (ii) is robust to stochasticity introduced by detectors/observing conditions. Reinforcement learning (RL) approaches allow agents to implicitly learn the physics/detector dynamics and the behavior policy that maximize a designated objective through experience.

To demonstrate the utility of such an approach for the kilonova follow-up problem, we train a toy RL agent for the goal of maximizing follow-up photometry for the true kilonova among several contaminant transient light curves. In a simulated environment where the agent learns online, it achieves 3x higher accuracy compared to a random strategy. However, it is surpassed by human agents by up to a factor of 2. This is likely because our hypothesis function (Q that is linear in state-action features) is an insufficient representation of the optimal behavior policy. More complex agents could perform at par or surpass human experts. Agents like these could pave the way for machine-directed software infrastructure to efficiently respond to next generation detectors, for conducting science inference and optimally planning expensive follow-up observations, scalably and with demonstrable performance guarantees.

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Session Classification: Contributed talks

Track Classification: Online