DEEP LEARNING TO ENABLE REAL-TIME GRAVITATIONAL WAVE AND MULTIMESSENGER ASTROPHYSICS

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Enlightened by light and astroparticles

What about events that do not emit light?
From darkness to sound

Some of the most fascinating astrophysical phenomena are governed by strong gravitational interactions

Numerically simulate extreme astrophysical environments using supercomputers
From darkness to sound

The most sensitive detectors ever constructed by humankind

LIGO Livingston

LIGO Handford

https://www.kaistaats.com/film/ligo-detection/
Detecting gravitational waves with LIGO requires measuring the distance between the Earth and Proxima Centauri with a precession better than a few microns!

4.24 light years
XXI century physics
The discovery of the century

There is much more than collisions of black holes

Collisions of neutron stars and black hole-neutron stars are expected to produce electromagnetic and astroparticle counterparts:
the holy grail of multimessenger astrophysics
What have we accomplished?

Gravitational waves have been detected

Confirmed: binary systems of black holes form and coalesce within the age of the Universe

Worldwide effort brought together a rich ecosystem of scientists: experimental and theoretical physicists, computer scientists, HPC, HTC, OSG, data analysts, outreach
$G_{\mu\nu} = 8\pi T_{\mu\nu}$

Detected: binary black holes
Future: supernovae collapse, gamma-ray bursts, oscillating neutron stars...
What is happening now?

More detectors, more data, more opportunities, more resources (?)

Kilometer scale multidetector network

Longer gravitational wave detection campaigns

More sensitive detectors

(C) LIGO
Computational challenges

Network throughput of gravitational wave data transfer is 1MB/sec. Raw data are a factor 10-30 larger.

Gravitational wave searches currently target a narrow class of astrophysical events (3D). Increasing the depth of existing searches is computationally prohibitive (8D).

Some types of gravitational wave signals go unnoticed with existing detection algorithms.
Computational challenges

Current and future portfolio of NSF-supported National Computing Resources

Complements Larger Aggregate Investments from Universities and other Agencies

Key:
Blue: Large-scale computation
Red: Long-tail and high-throughput
Green: Data Intensive
Orange: Cloud

Leadership HPC Planning 2 to 3x Time-To-Solution Improvement > 20x Improvement
It is time to connect our successful present with a bright future.

Current challenges can only be overcome through innovation.

Leverage existing HPC and HTC infrastructure with recent breakthroughs in artificial intelligence.