AI for science: a view from physics & astronomy
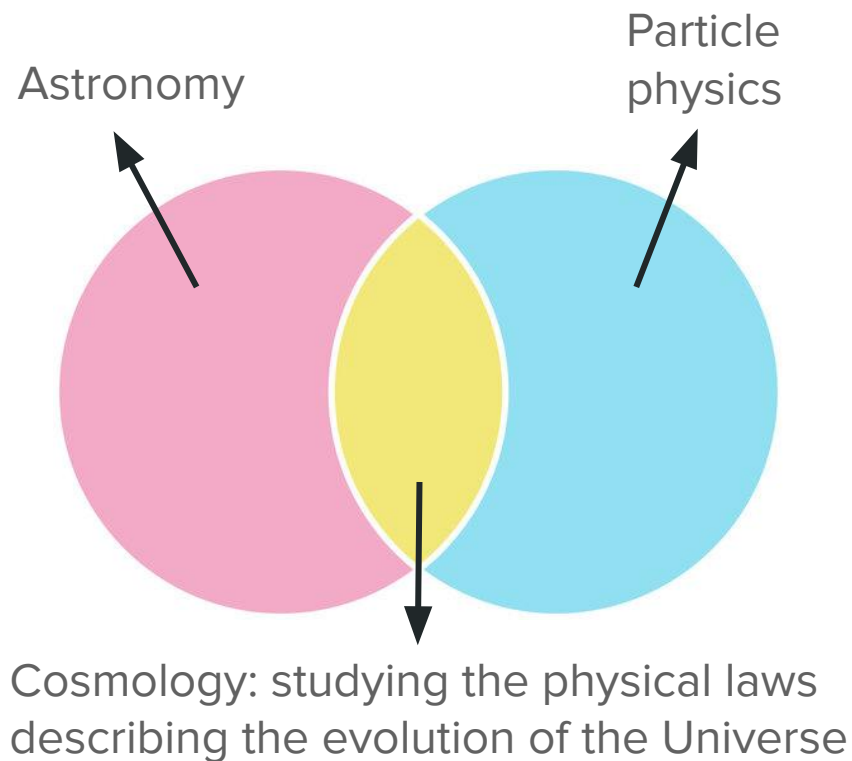
Rachel Mandelbaum (Carnegie Mellon University)
NAIAC panel, 2/22/2024

AI for fundamental physics

Using AI to understand the basic physical laws describing the very smallest and very largest scales in the Universe comes with **distinct opportunities and challenges from AI for more application-driven sciences**.

Astronomy

Particle physics

Cosmology: studying the physical laws describing the evolution of the Universe

Pathways to Innovation and Discovery in Particle Physics

Report of the Particle Physics Project Prioritization Panel 2023

Exploring
the
Quantum
Universe

https://www.usparticlephysics.org/2023-p5-report/
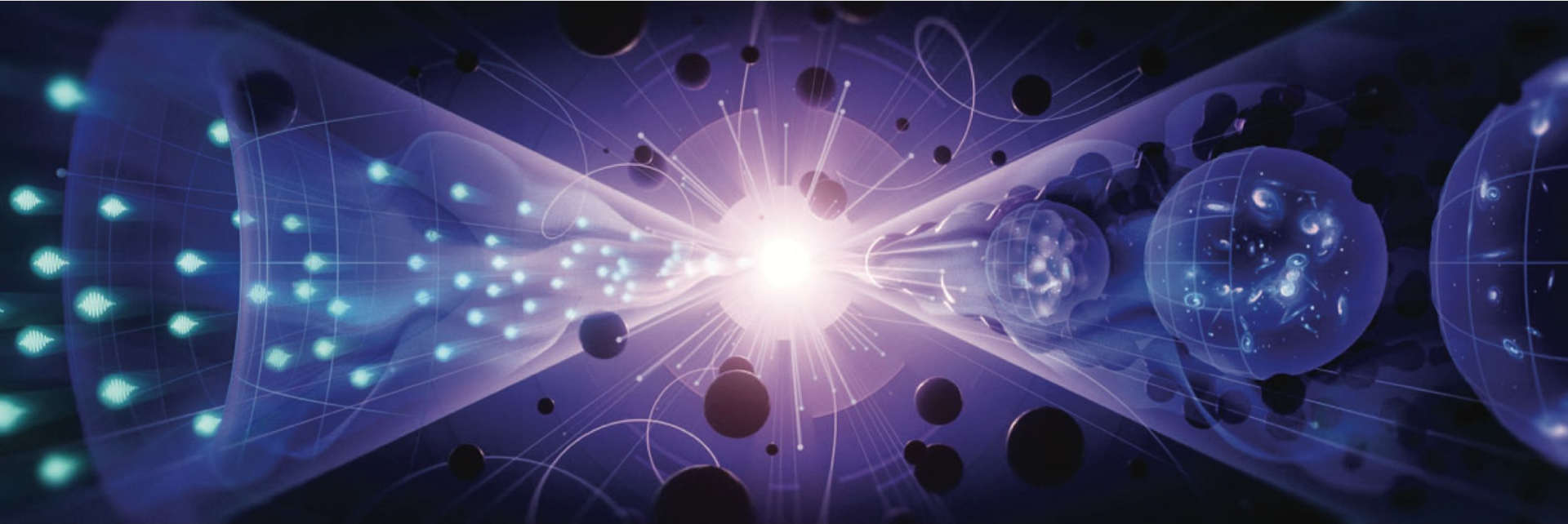
Pathways to Innovation and Discovery in Particle Physics

**Report of the Particle Physics Project Prioritization Panel 2023**

The US particle physics program currently includes three facilities at the billion-dollar scale:

Also: a broad portfolio of small- and medium-sized facilities and experiments; space-based observatories (NASA)

AI development could boost the scientific value of billion-dollar facilities and solidifies US scientific leadership!

- Survey astronomy & particle physics are entering a regime of very large, complex data streams: **limitations in analysis tools will be the main obstacle to scientific discovery**

- With sustained development, **AI may be our best hope of extracting the huge information content of our datasets**
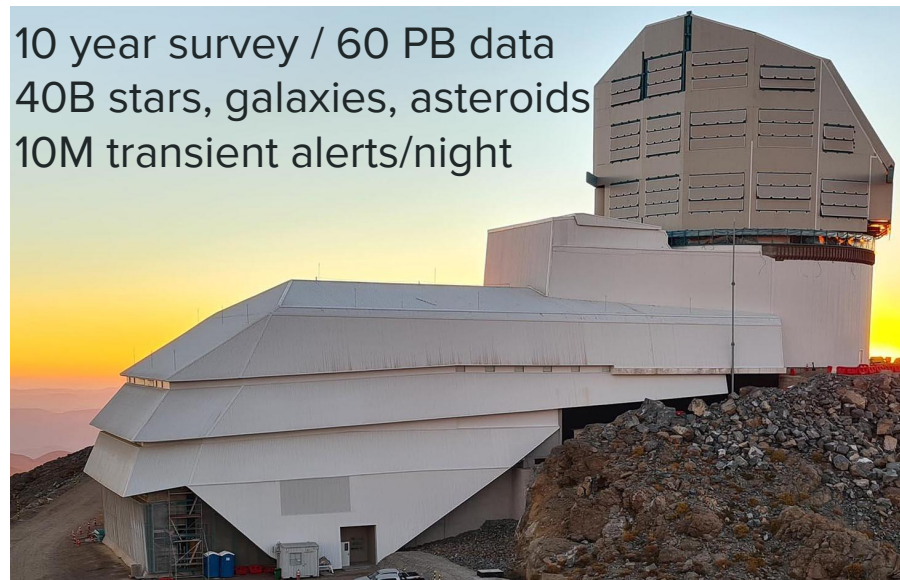
10 year survey / 60 PB data
40B stars, galaxies, asteroids
10M transient alerts/night

The Vera C. Rubin Observatory

Requirements to utilize AI to advance discovery

Despite enormous recent advances in AI, **much work must be done so that these methods can drive scientific progress**: AI methods must be robust, well-understood, and fit within the **scientific method**!

- AI must handle **complex datasets,** quantify statistical and systematic **uncertainty**, and provide **physics-based interpretations**.

- Physics/astronomy provide exceptional testing grounds to **advance the frontiers of AI**
    - Note large, open astronomical datasets; "AI on a chip" for particle physics

- Ultimately **benefits many fields and supports a robust STEM workforce**

Overcoming barriers to realizing this vision

1. **Sustained investment in AI driven science**: basic AI method development & software toolkits for AI at scale, in an integrated multi-disciplinary context

2. **Education:** Updated curricula & ways to upskill the current astronomy and particle physics communities

3. **New, interdisciplinary career paths**

4. **Robust national computing landscape,** both computing & storage (NAIRR!)

Overcoming these barriers will solidify and strengthen US scientific leadership, boost the scientific value of major US investments in facilities, support improved AI and the US STEM workforce more broadly!