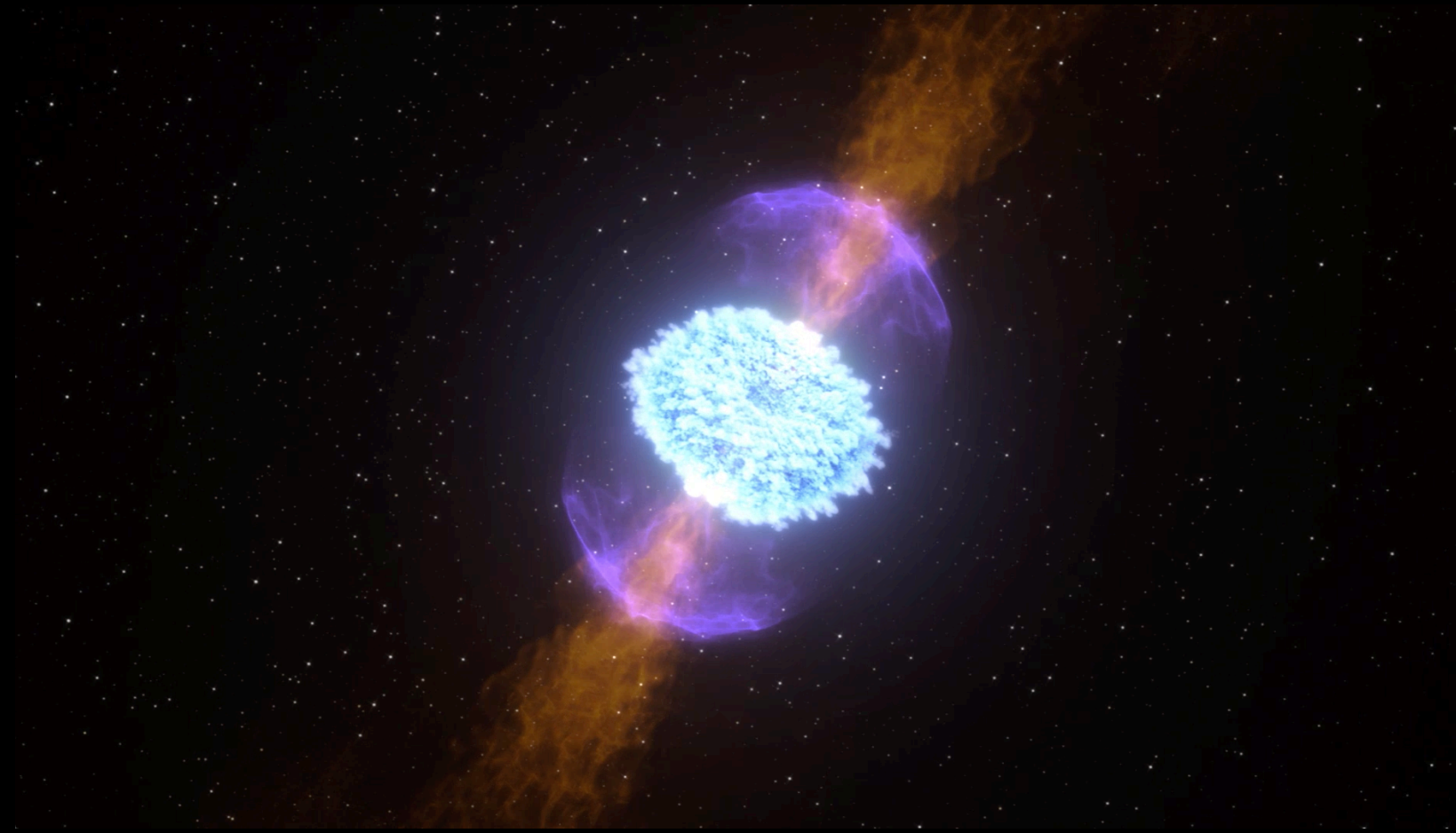


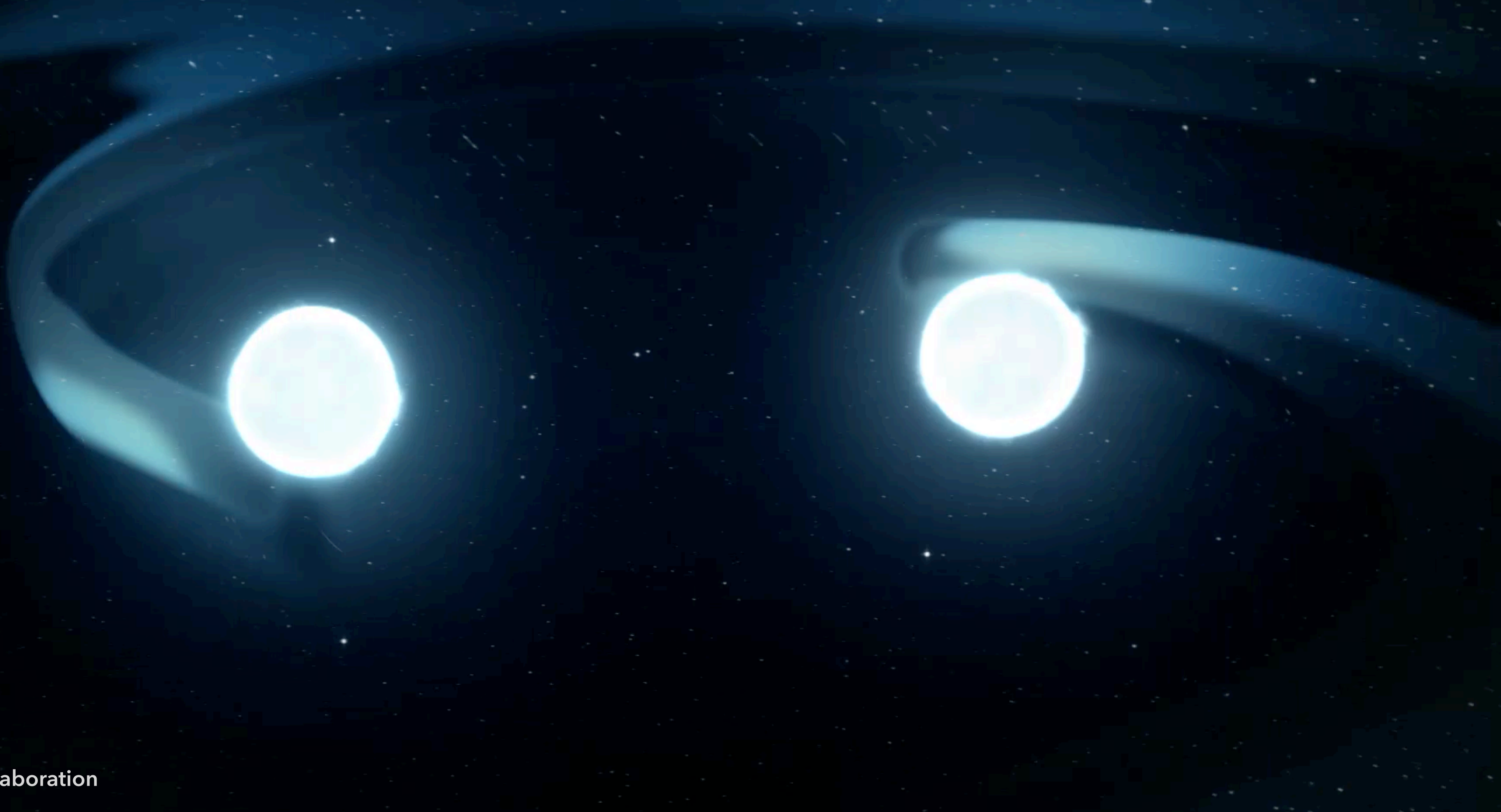
# Extreme Astrophysics



G. Bertone and S. Markoff

- ▶ ESCAPE Test Science Project: "A holistic approach to Black Holes"
- ▶ JENAS EoI: "Gravitational Waves for Fundamental Physics"
- ▶ About EuCAPT

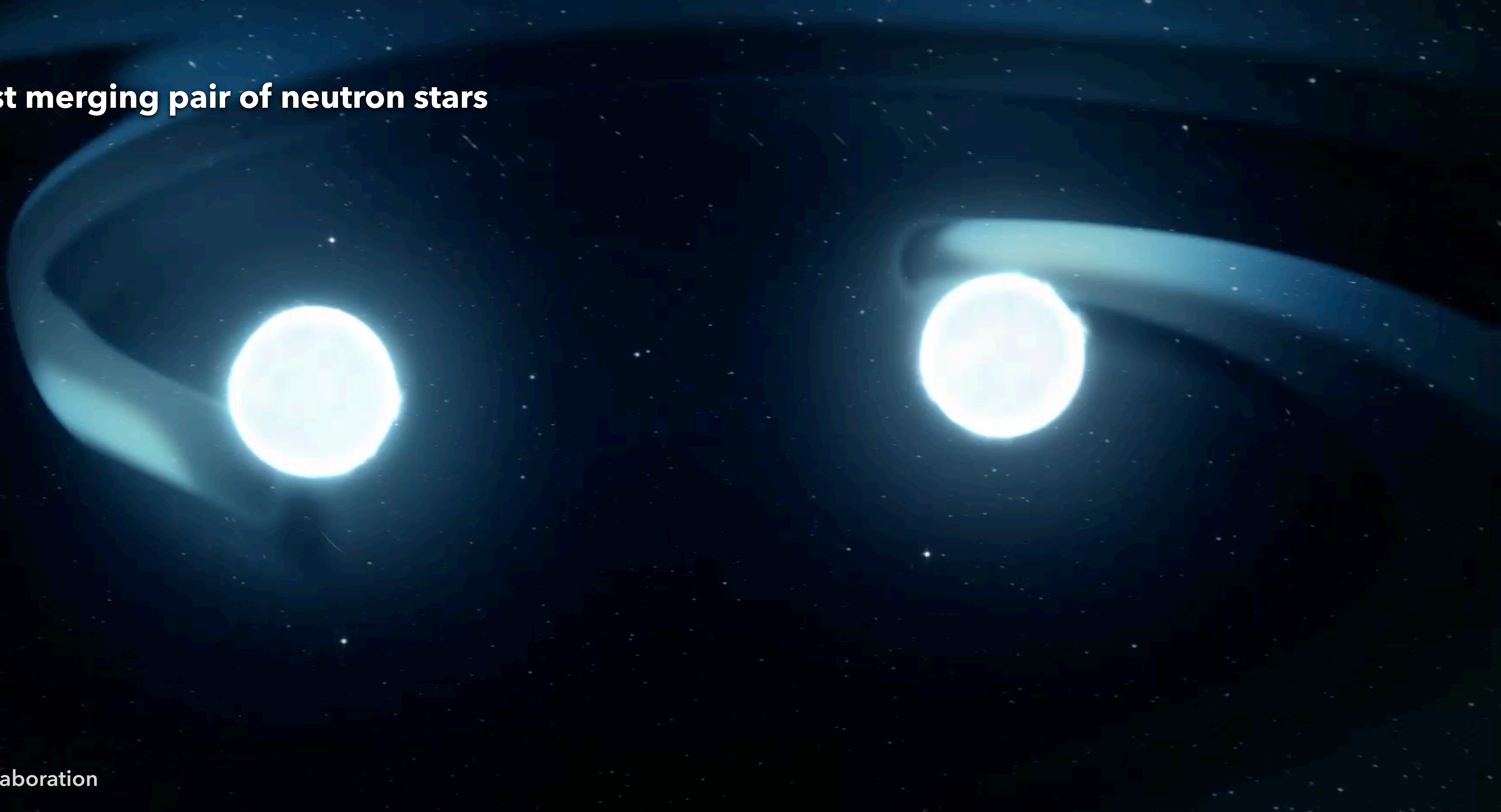
The 'frontier' for multi-messenger science is to understand extreme matter and particle processes in strongly curved spacetime





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**2017:** first merging pair of neutron stars

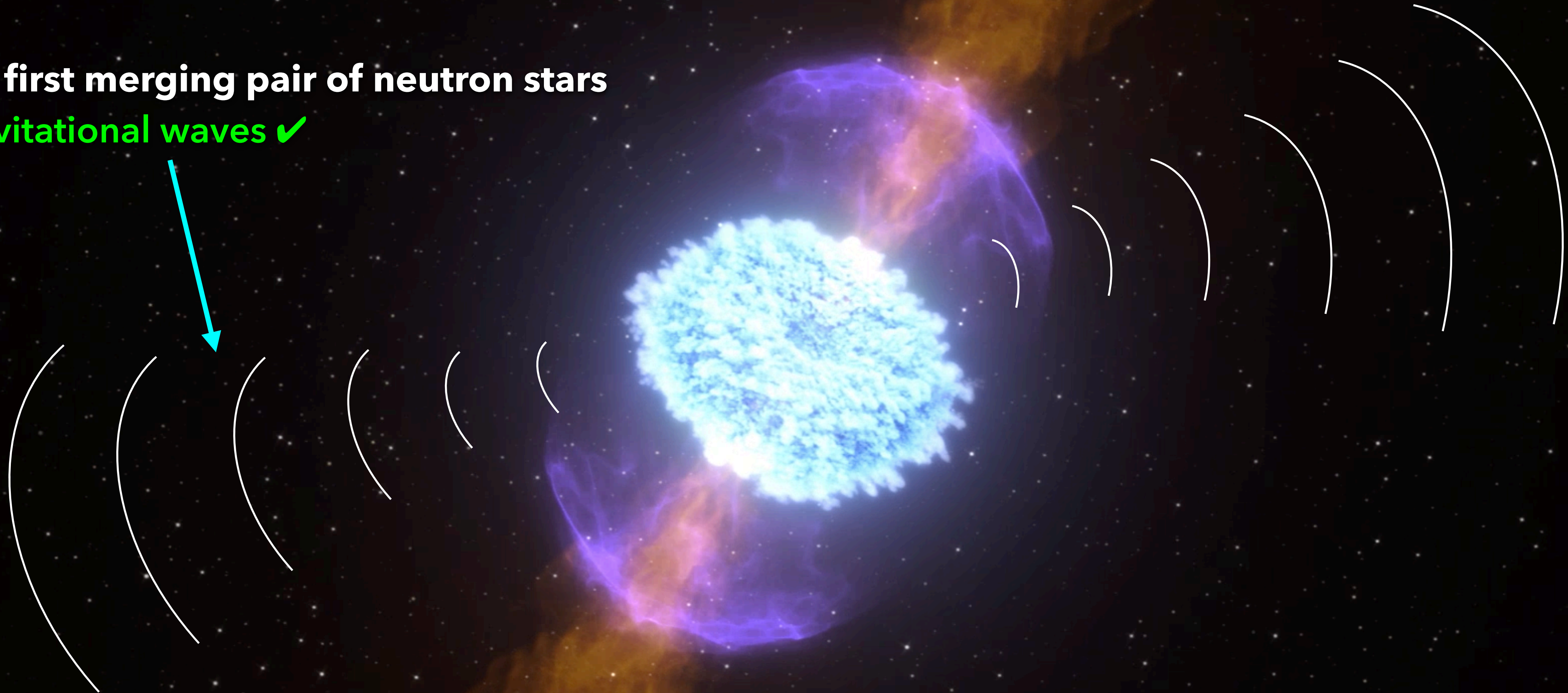




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→ Gravitational waves ✓

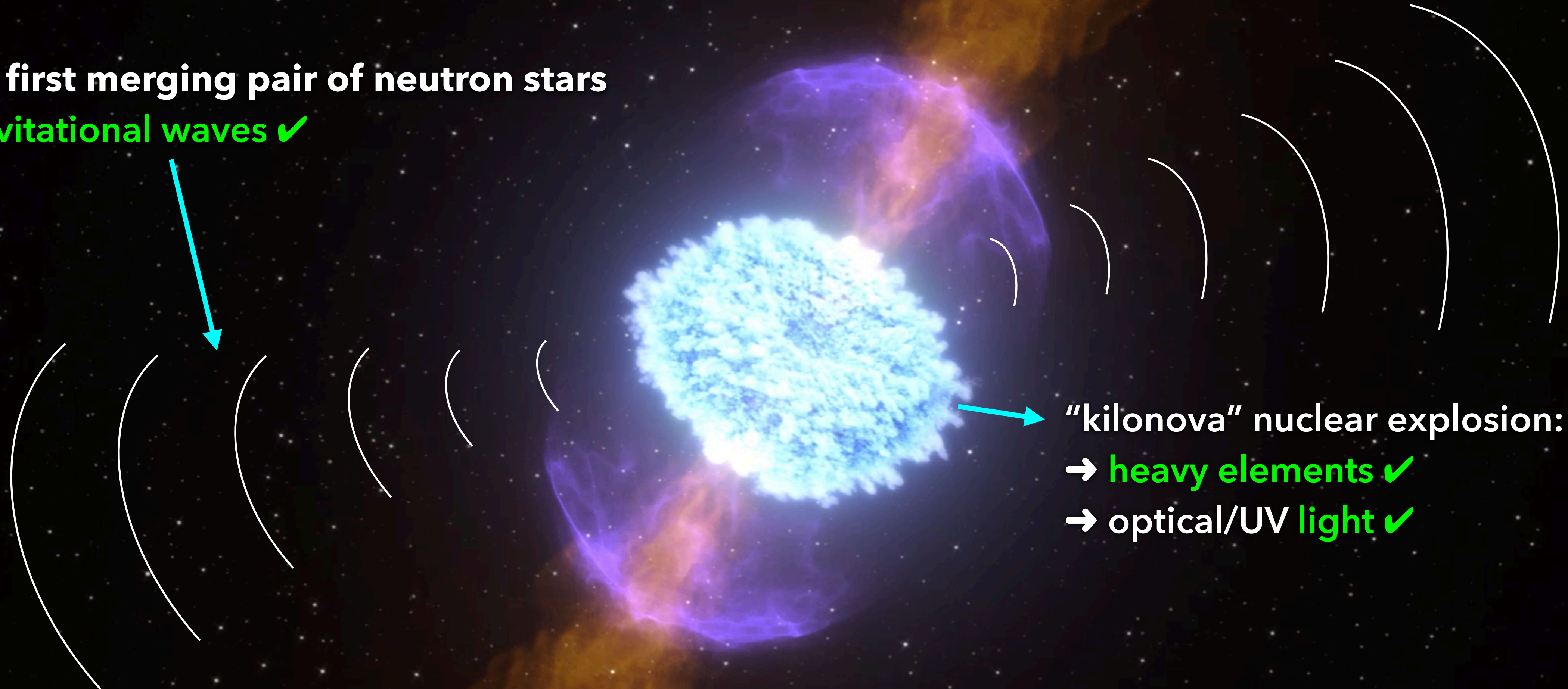




# The 'frontier' for multi-messenger science is to understand extreme matter and particle processes in strongly curved spacetime

**2017: first merging pair of neutron stars**

→ **Gravitational waves** ✓



**"kilonova" nuclear explosion:**

→ **heavy elements** ✓

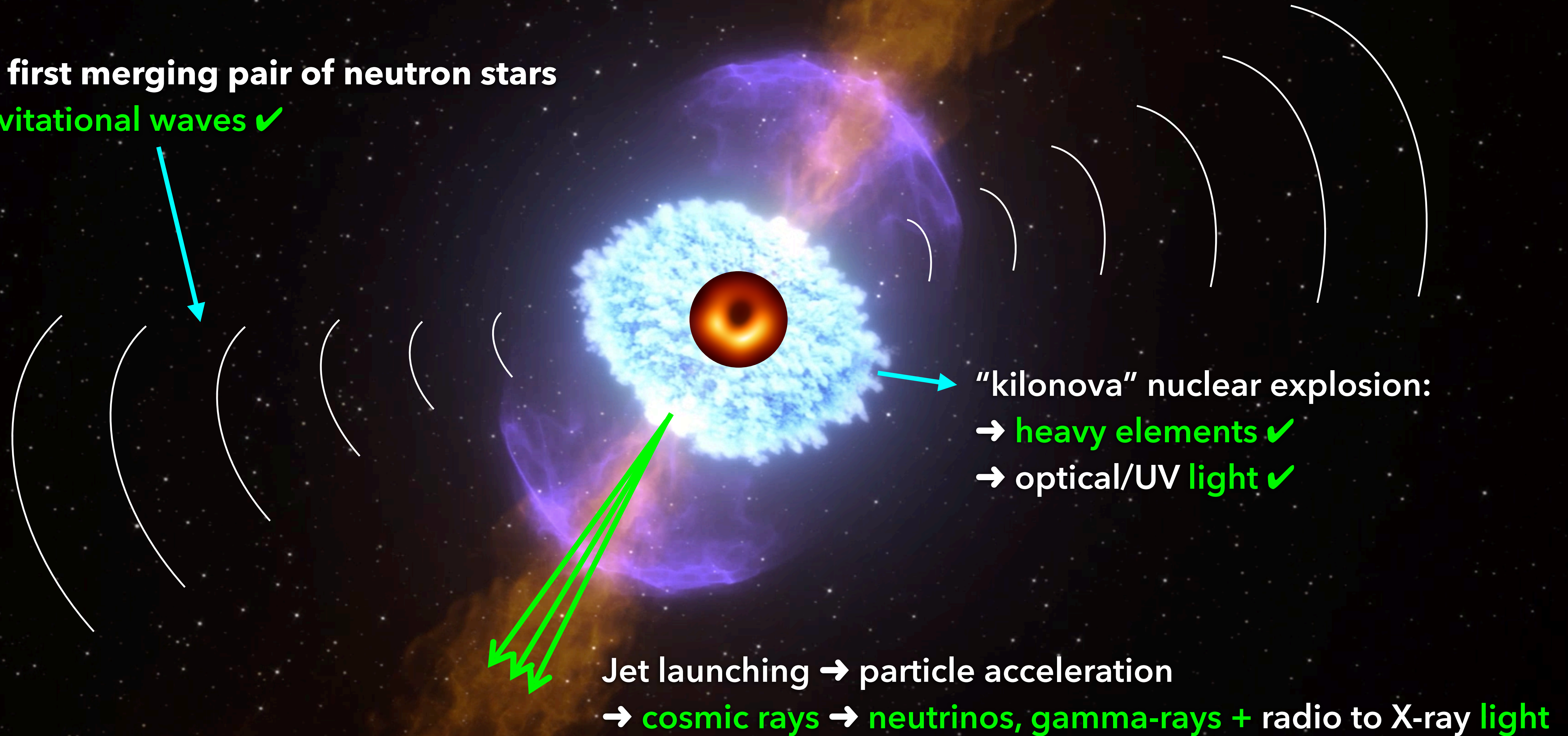
→ **optical/UV light** ✓



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→ **Gravitational waves** ✓

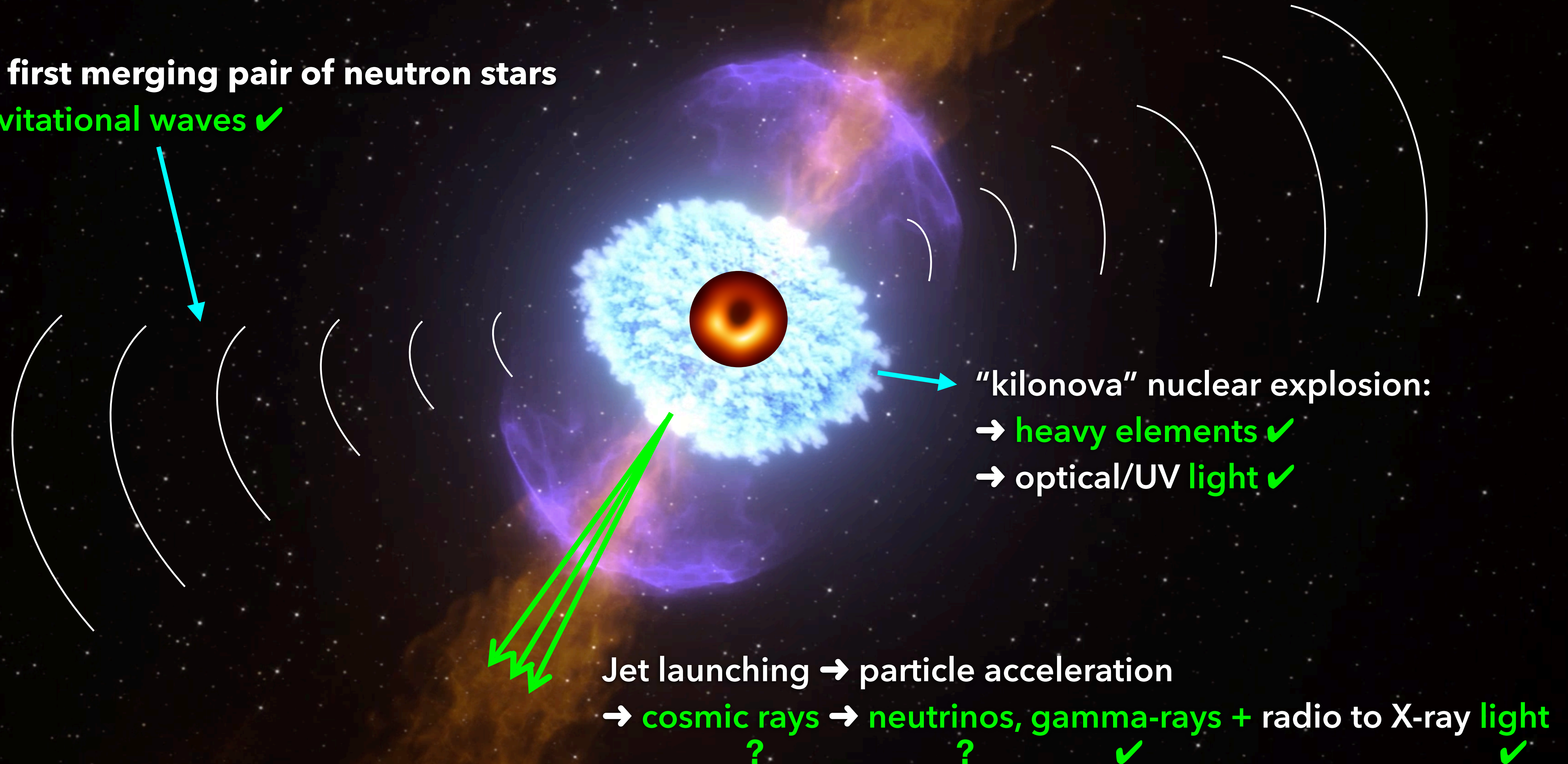




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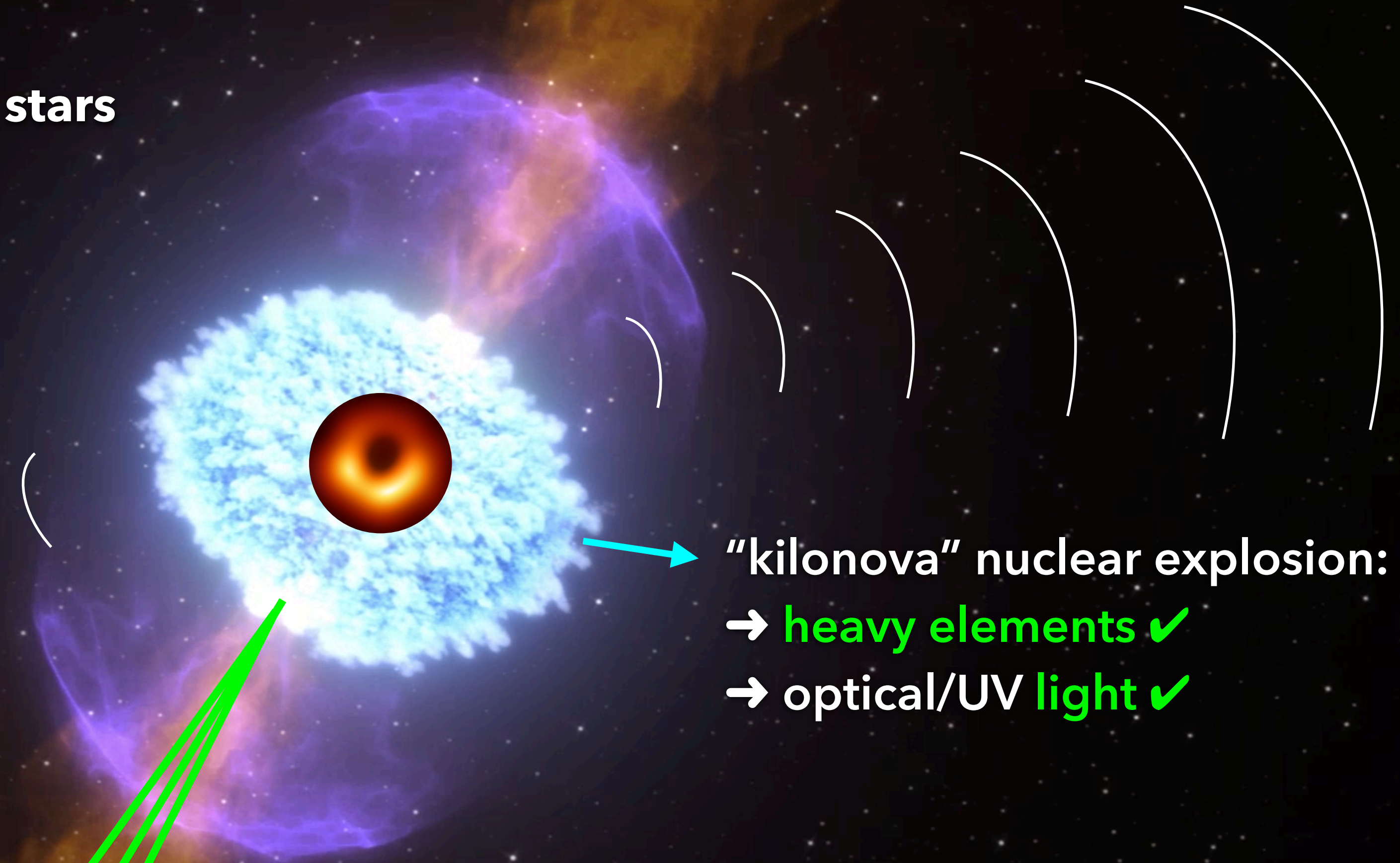
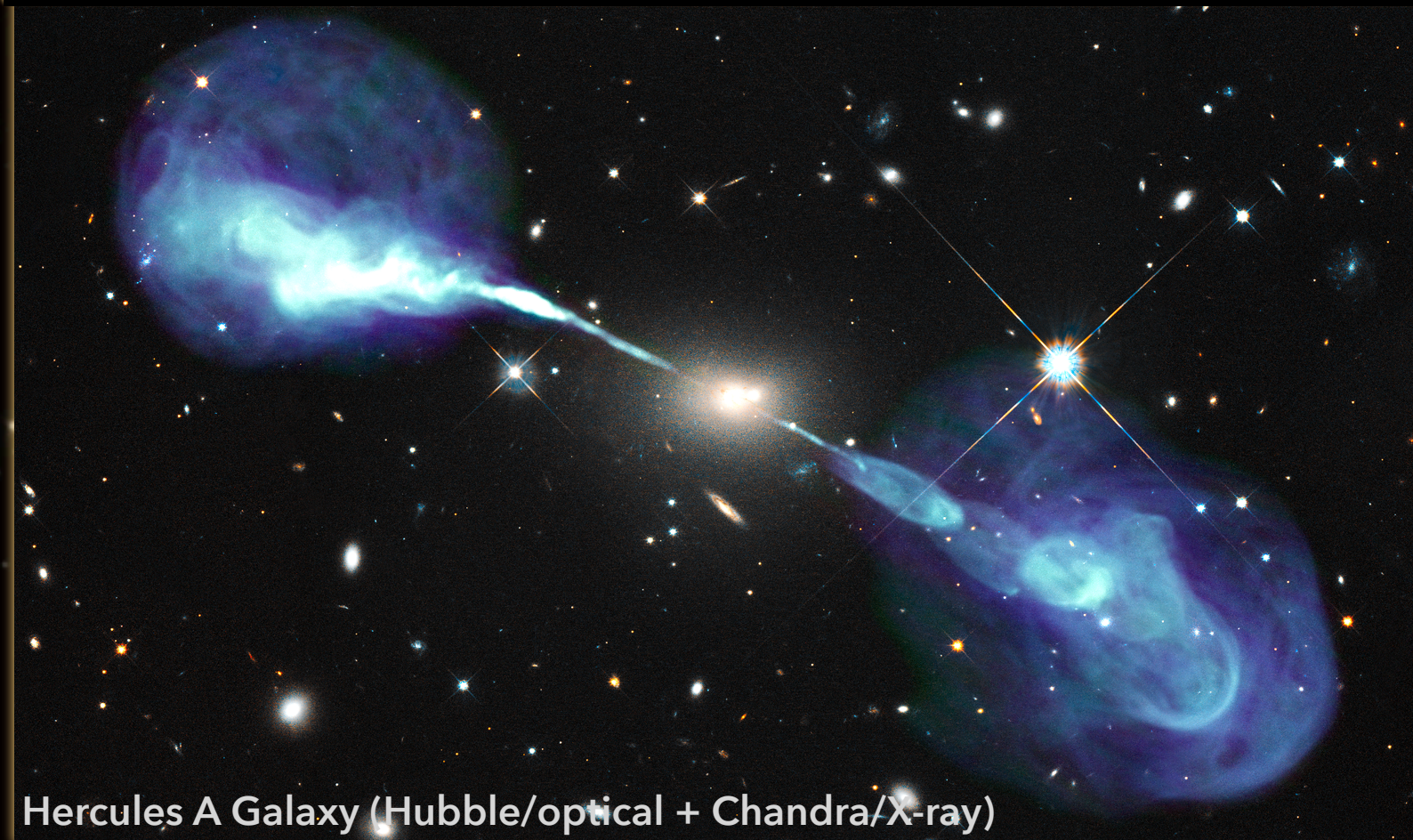


# The 'frontier' for multi-messenger science is to understand extreme matter and particle processes in strongly curved spacetime

**2017:** first merging pair of neutron stars

→ **Gravitational waves** ✓

**2018:** first **neutrino** (✓) detected from supermassive black hole jets



"kilonova" nuclear explosion:

→ **heavy elements** ✓

→ **optical/UV light** ✓

Jet launching → particle acceleration

→ **cosmic rays** ? → **neutrinos** ? → **gamma-rays** ✓ + radio to X-ray **light** ✓

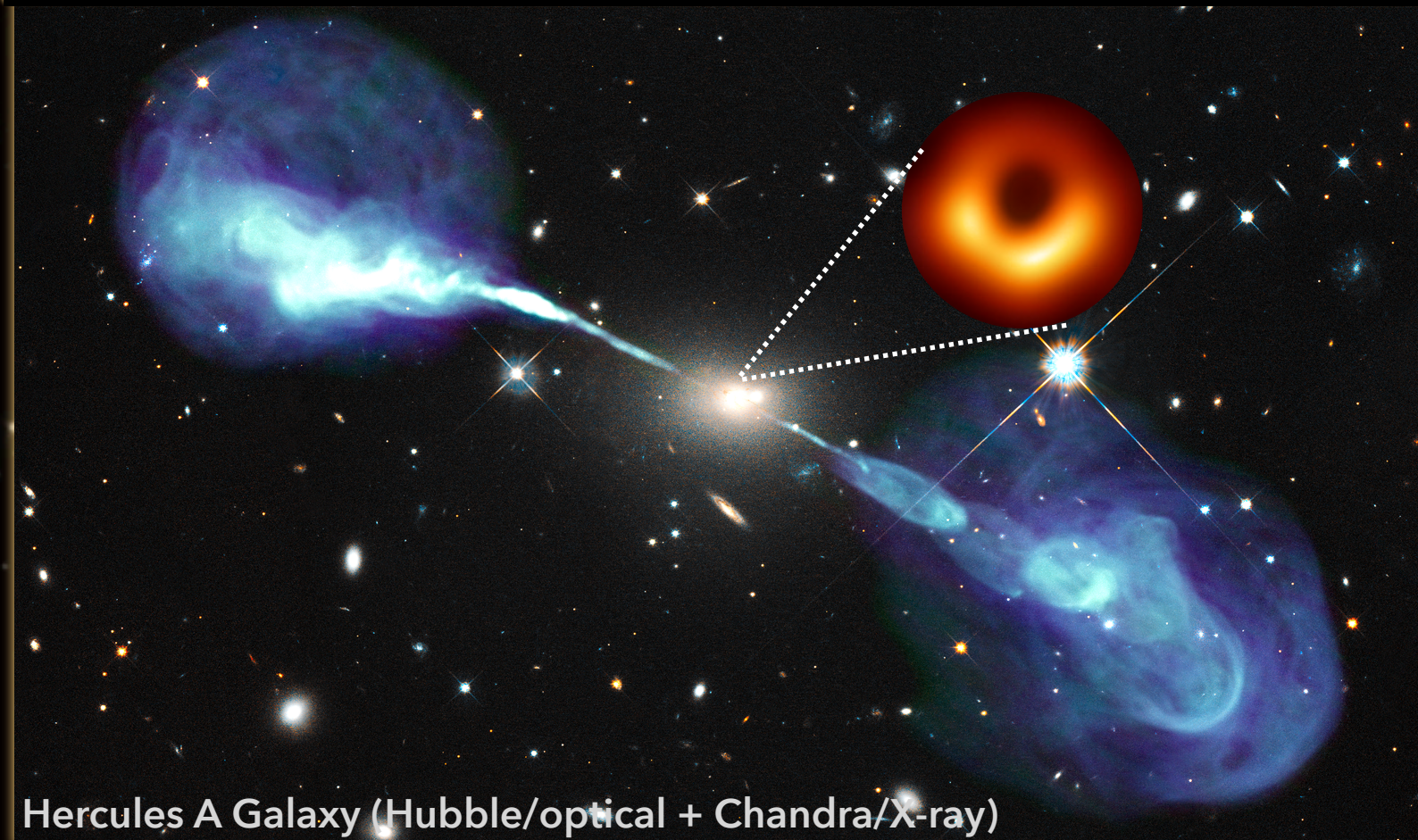


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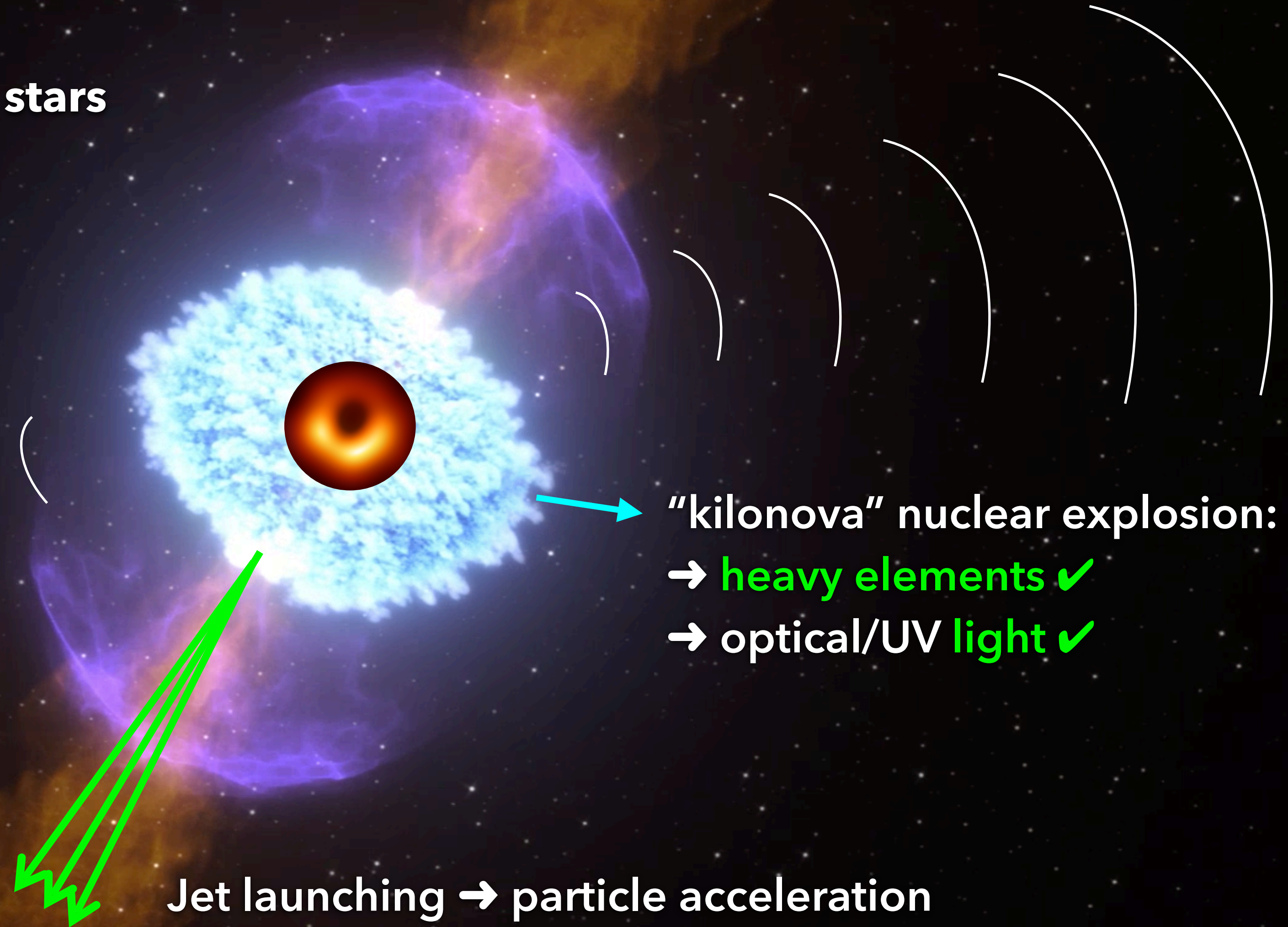
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Hercules A Galaxy (Hubble/optical + Chandra/X-ray)

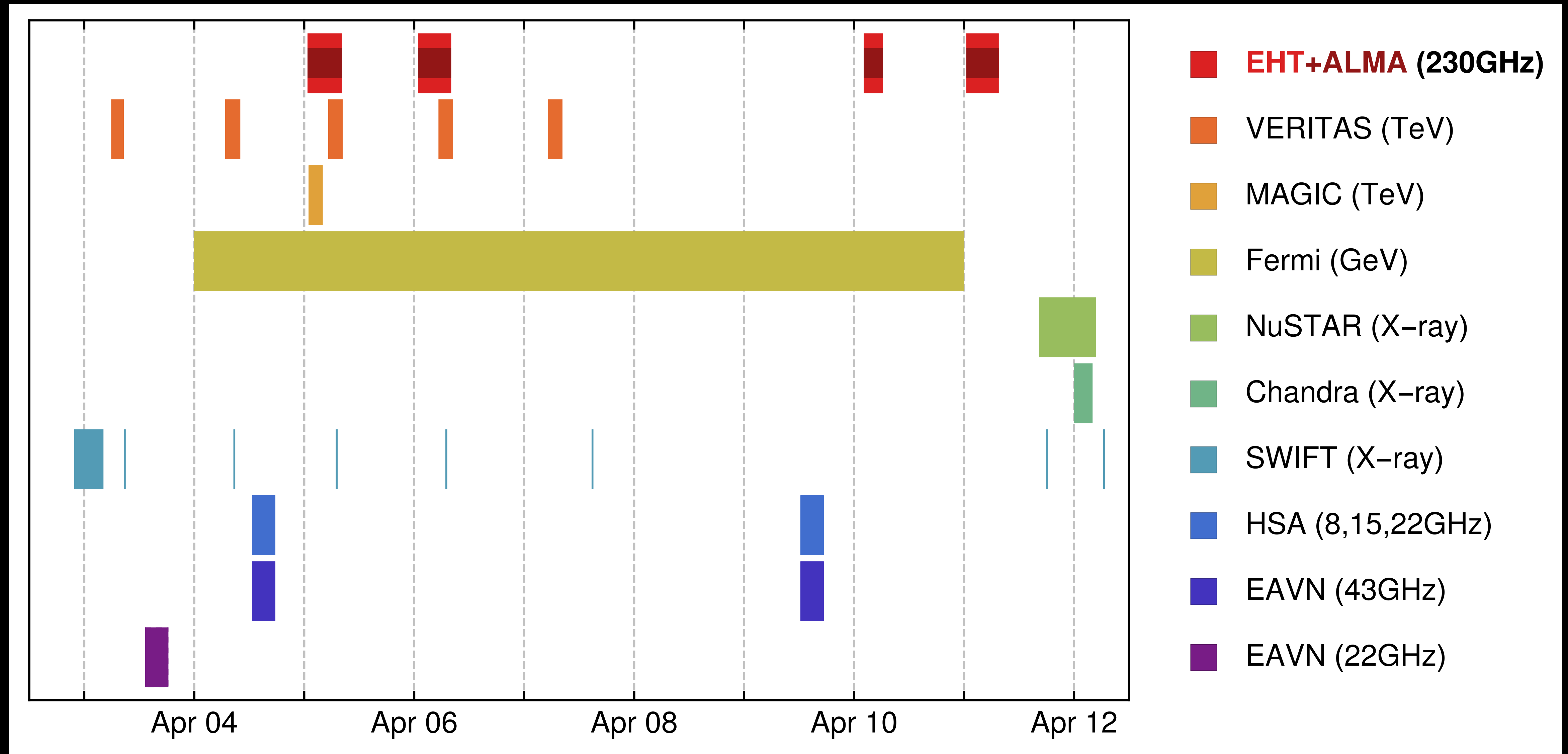


Jet launching → particle acceleration

→ **cosmic rays** ? → **neutrinos** ? → **gamma-rays** ✓ + radio to X-ray **light** ✓



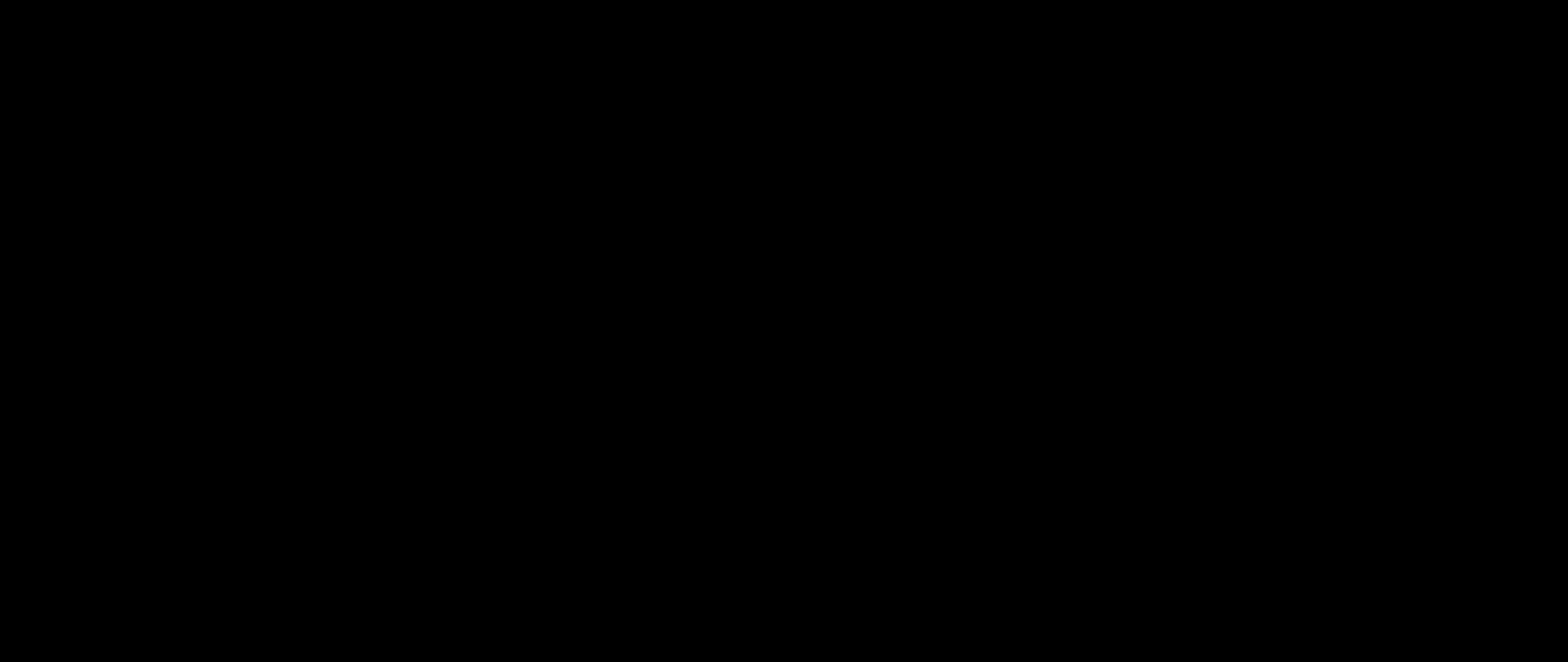
The Event Horizon Telescope used MWL constraints to reject half of the theoretical model scenarios. A key question is whether these jets also accelerate cosmic rays/neutrinos.



(M. Johnson, J. Farah/UMass, S. Markoff & K. Hada, for EHT MWL WG)



# ESCAPE TSP: "A holistic approach to Black Holes"





# ESCAPE TSP: "A holistic approach to Black Holes"

- ▶ Similar physics at the heart of EM counterparts of GW events and many cosmic accelerators
- ▶ Major outstanding questions:
  - how does strong gravity interact with/influence strongly magnetised plasma?
  - what governs how gravitational energy is channeled into different forms?
  - are astrophysical jets the source of high-energy cosmic rays and neutrinos?
  - how can we predict fluxes of photons and other signals from first principles?
- ▶ ESCAPE Test Science Project: platform where data from data from different wavelengths/messengers can be easily gathered, analysed and modelled holistically, not piecemeal as currently done



# JENAS EoI: "Gravitational Waves for Fundamental Physics"

Gravitational waves (GW) are ripples in the fabric of spacetime, predicted by Einstein's theory of General Relativity. They are produced by the acceleration of massive objects, such as black holes, neutron stars, and supernovae. The detection of GWs has opened a new window into the universe, allowing us to observe events that were previously invisible to electromagnetic observations.

The JENAS EoI (European Open Initiative) for Gravitational Waves for Fundamental Physics is a collaborative effort between scientists from various European countries, including Germany, France, Italy, and the UK. The initiative aims to coordinate research efforts, share resources, and promote the development of new technologies for GW detection.

The JENAS EoI is currently in the early stages of development. It will focus on the following areas:

- **Research Coordination:** Organizing workshops, conferences, and seminars to facilitate the exchange of ideas and information between scientists.
- **Resource Sharing:** Establishing a common database of GW detection results and sharing access to existing GW detection facilities.
- **Technology Development:** Promoting the development of new technologies for GW detection, such as advanced laser interferometers and data analysis techniques.

The JENAS EoI is a key component of the European Space Agency's (ESA) efforts to advance the field of gravitational wave astronomy. It will play a central role in the development of the next generation of GW detectors, which are expected to be operational in the coming years.

The JENAS EoI is a testament to the power of international collaboration in science. By working together, scientists from different countries can pool their resources and expertise to achieve breakthroughs that would be impossible for any one country to achieve on its own.

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# JENAS EoI: "Gravitational Waves for Fundamental Physics"

- ▶ Another initiative that we are considering is a platform on "Gravitational Waves for Fundamental Physics" in the framework of JENAS
- ▶ GWs may in fact soon probe:
  - ▶ the particle nature of dark matter, e.g. via BH environments (ApPEC / ECFA)
  - ▶ the properties of extreme nuclear matter, via NS mergers (ApPEC / NuPECC)
  - ▶ new physics in the early universe, via phase transitions (ApPEC / ECFA)
- ▶ We plan to probe the interest of the community and consider submitting an EoI



# Open issues and challenges

• **Integration of different data sources**

• **Development of new algorithms**

• **Validation and benchmarking**

• **Interpretability and explainability**

• **Scalability and efficiency**

• **Privacy and security**

• **Collaboration and community**

• **Ethical considerations**



# Open issues and challenges

- ▶ How to build an optimal interface between scientists and ESCAPE?
- ▶ Major issues:
  - software development scarcely rewarded in academic environments (difficult to attract funds & work not always recognised)
  - need suitable resources to build and maintain VRE
  - Timescale of (theoretical) research, e.g. in MM Astrophysics vs. Building general-purpose frameworks
- ▶ Focus on 1 TSP within ESCAPE, or explore many smaller test cases?



# About EuCAPT

European CAPTivity

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# About EuCAPT

- ▶ European Consortium for Astroparticle Theory
- ▶ New initiative, with central hub at CERN and support of APPEC, that aims to bring together the European community of theoretical astroparticle physicists and cosmologists.
- ▶ 1st census: 660 theorists working in 31 European countries, 55 nationalities
- ▶ •Goals:
  - ▶ *to increase the exchange of ideas and knowledge;*
  - ▶ *to coordinate scientific and training activities*
  - ▶ *to help scientists attract adequate resources for their projects*
  - ▶ *to promote a stimulating, fair and open environment in which young scientists can thrive*