Detectable MeV Neutrinos from

COMMON ENVELOPE EVOLUTION

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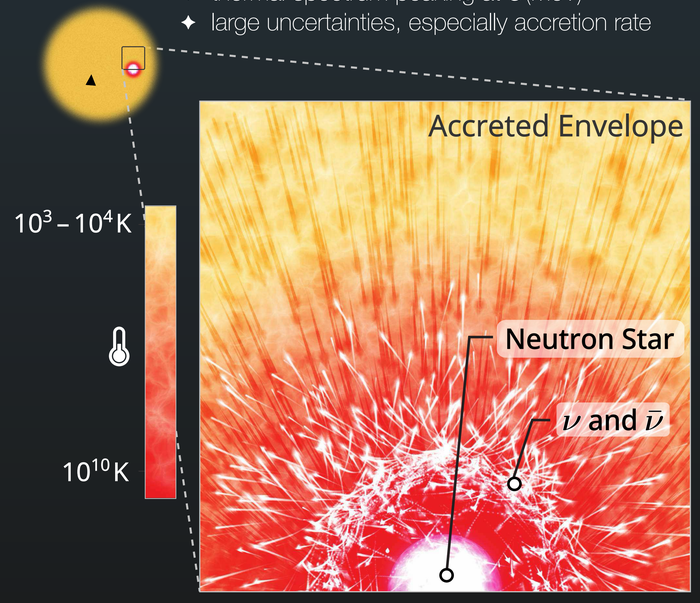
Abstract

Common-envelope evolution, where a **neutron star or black hole is engulfed by a companion**, is a critical step in the **formation pathways for gravitational-wave sources and X-ray binaries**. But it has never been directly observed.. We show that the hypothesized super-Eddington accretion during a common-envelope event would produce **months-long neutrino signals in the MeV range that are within reach of present and planned detectors**. While there are substantial uncertainties on the rate of such events (0.01–1/century in the Milky Way) and the neutrino luminosity, a search for such a signal in archival or upcoming data could lead to significant new insights into the astrophysics of common-envelope evolution, thereby answering long-standing open questions in astrophysics.

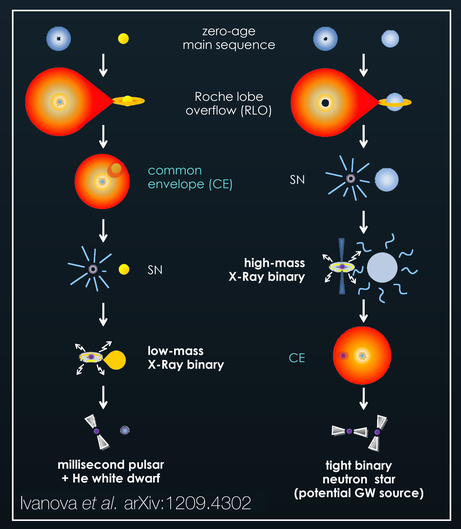
Neutrino Emission

- huge accretion rates during CEE (up to 0.1 $M_\odot$ /yr)
- **gravitational energy release** leads to heating
- photons trapped ➠ not an efficient cooling channel
- **neutrino cooling!** ($e^+e^- \to \nu\bar{\nu}$, $\gamma^* \to \nu\bar{\nu}$)
  - in addition: kinetic energy release (explosion?)
  - thermal spectrum peaking at $\mathcal{O}$(MeV)
  - large uncertainties, especially accretion rate



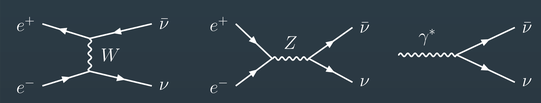
Astrophysical Context

- critical step in the formation of **X-ray binaries** and **GW sources**
- theoretically poorly understood
- **never directly observed**
- duration $\mathcal{O}$(months–years)
- very rare: (0.01–1 / century)

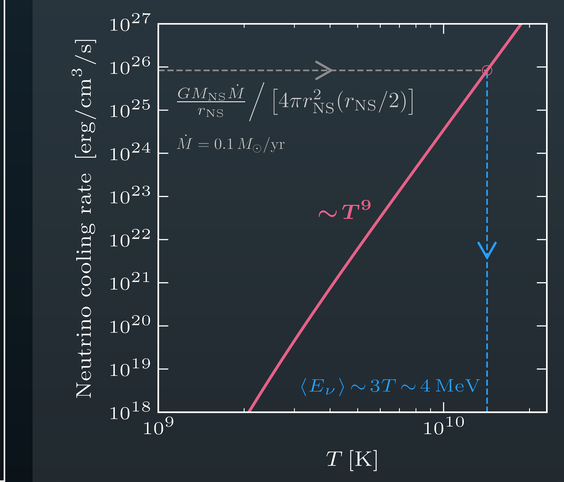


Ivanova *et al.* arXiv:1209.4302

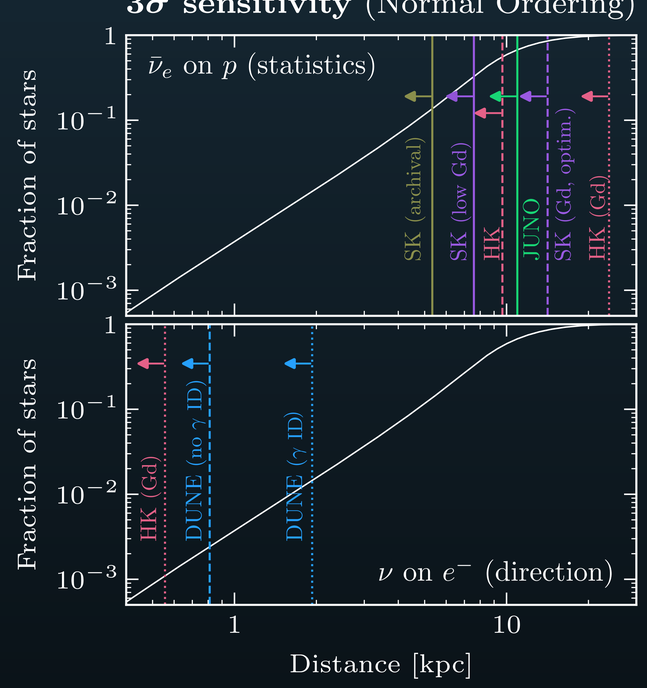
Neutrino Spectrum



- thermal spectrum
- accretion rate determines temperature
- neutrino flux ∝ accretion rate



Distance Reach



Detection

DUNE

ν–e scattering *(directional)*

Backgrounds

- neutrons
- spallation products
- solar ν must be suppressed (directionality / γ from ^{40}Ar*)

SuperK (archival w/o Gd)

inv. β decay *(non-directional)*

Backgrounds

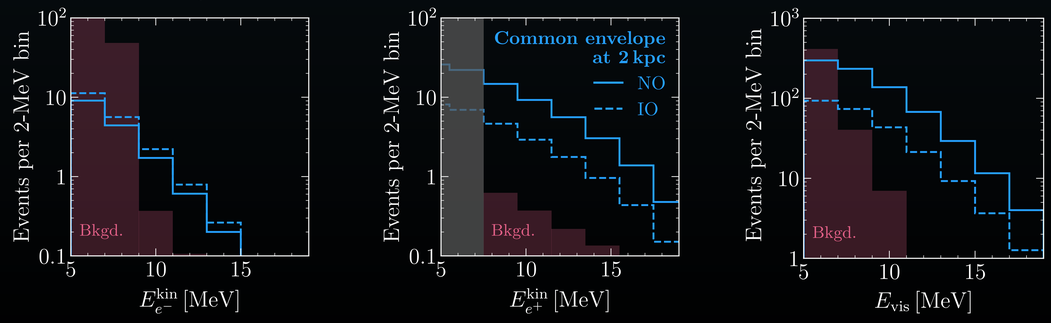
- accidental
- ^{9}Li from spallation
- atmospheric ν via NC

JUNO

inv. β decay *(non-directional)*

Backgrounds

- reactor ν
- ^{9}Li and ^{8}He from spallation
- atmospheric ν via NC



Take-Home Message

- **new astrophysical neutrino source**
- **detectable anywhere in our galaxy**
- very **rare**, but payoff of detection would be huge
- many astrophysical uncertainties, which neutrino observations could help resolve
- **requires dedicated search strategy** (excess in ν event rate lasting ~months)
- signal could be hidden in existing data

Ivan Esteban, John Beacom, JK, *Detectable MeV Neutrino Signals from Neutron-Star Common-Envelope Systems*, Phys. Rev. Lett. 134 (2025) 18, 181003, **arXiv:2310.19868**

code for computing hydrodynamic profiles and neutrino spectra available on **GitHub**: https://github.com/ivan-esteban-phys/common-envelope-thermal

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