Revealing the progenitors of gravitational waves mergers with neural networks

Courty Théo - 1st year PhD
Biennale 2026

Group: Gravitation

Supervisors: Sylvain Chaty & Eric Chassande-Mottin

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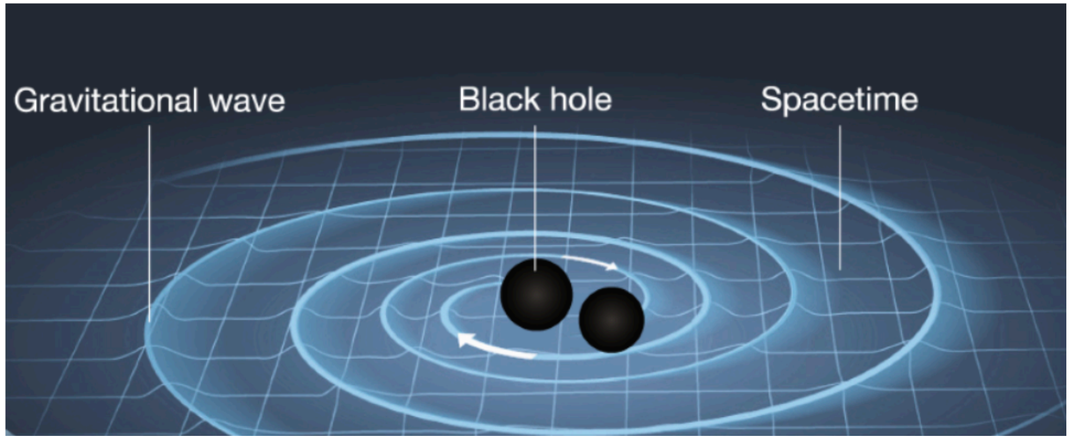
Gravitational waves & black holes population

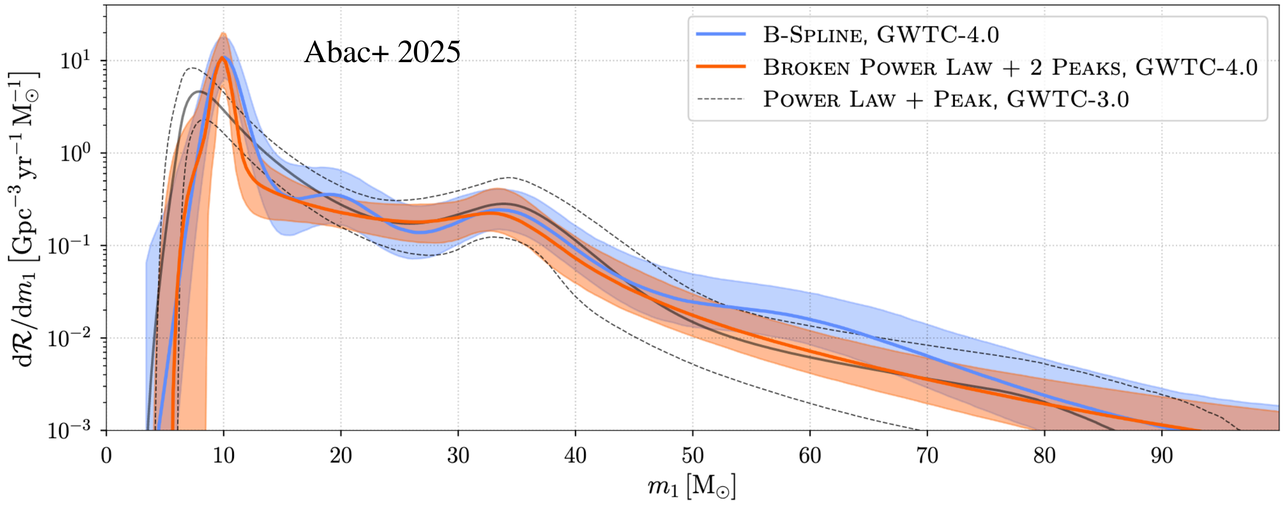


Virgo detector

Hundreds of events detected

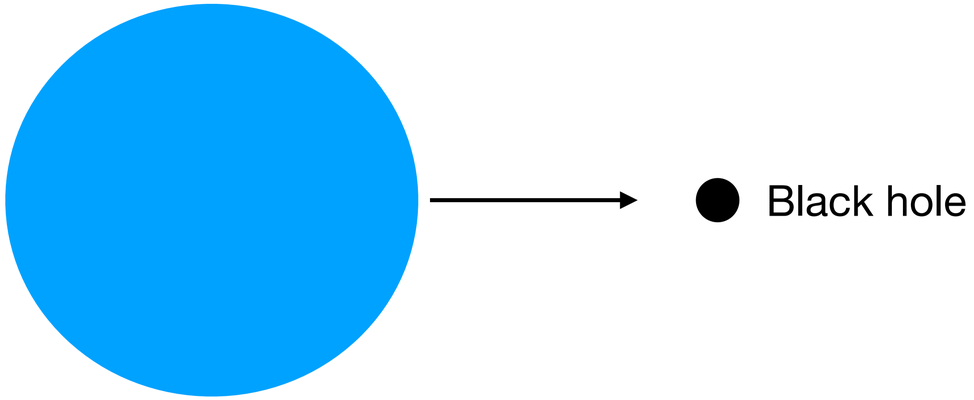
What are the **formation channels** of these black holes?

What are the links between binary black holes population and stellar astrophysics?

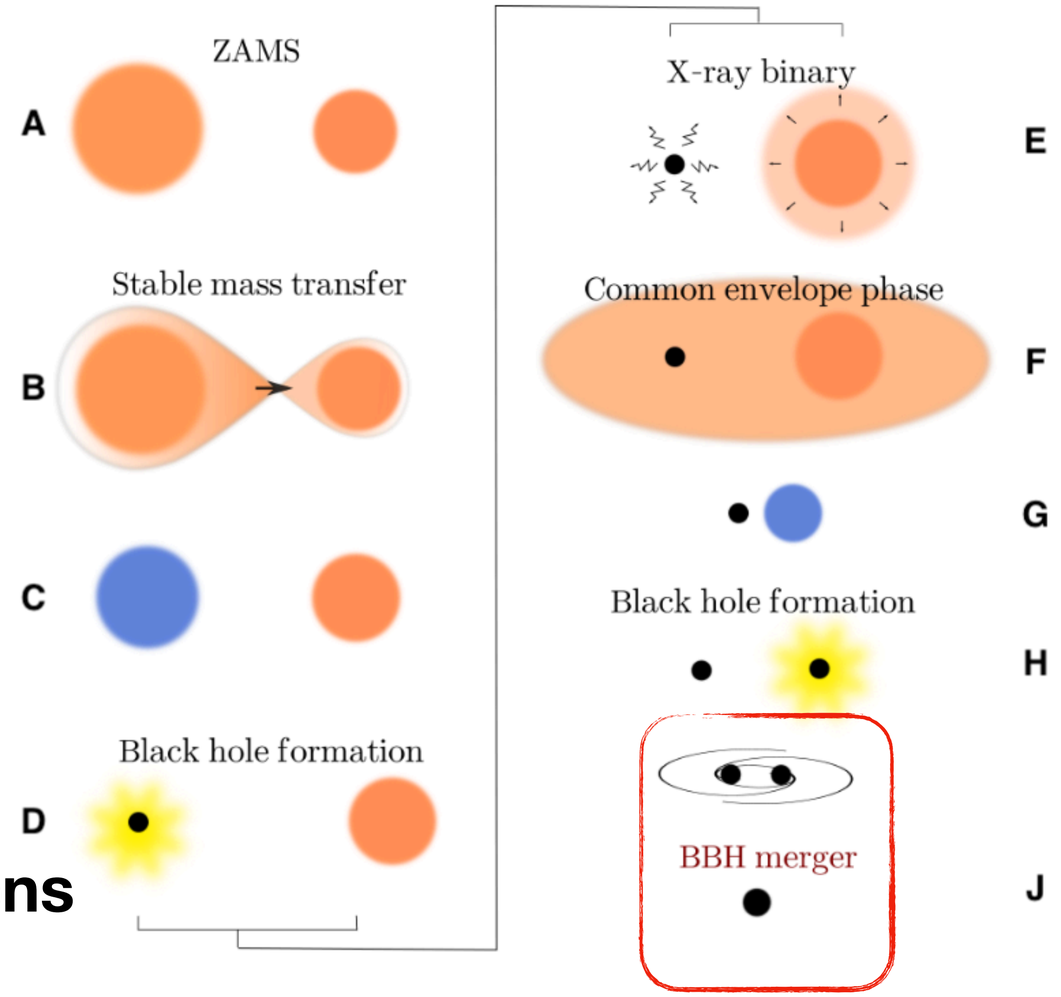


Compact object formation from stellar evolution

Initial star **Remnant**



García+ 2021

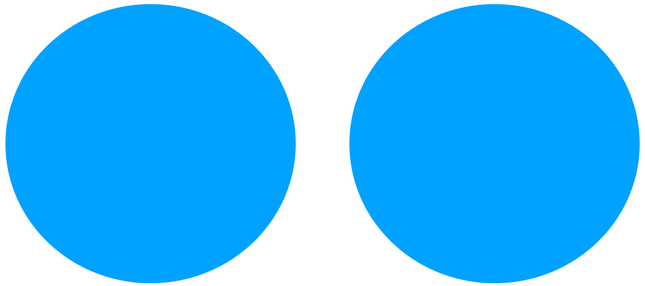


- Black holes are end of massive star evolution
- Binary systems = strong **interactions**!
- Detectable mergers need very **specific conditions**
- **Complex** and poorly constrained scenario

Gravitational waves observations

My PhD in a nutshell

Initial binary properties X



X = (Masses, metallicity, orbital separation, eccentricity, rotations)

Numerical simulation

Hydrodynamic

Thermodynamic

Nuclear reactions

Orbital parameters

Final binary black hole Y

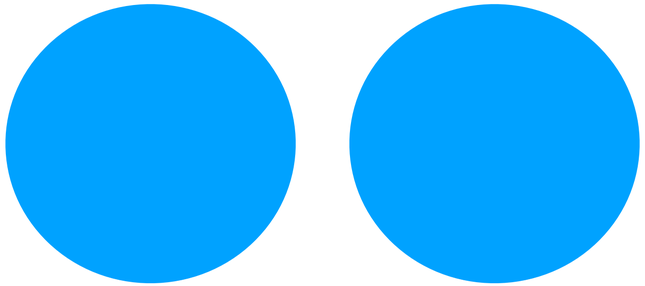
Y = (Masses, spins, orbital parameters)

Prohibitive computational time for population studies!

My PhD in a nutshell

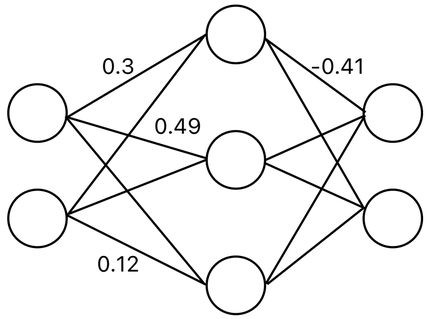
Initial binary properties X

X = (Masses, metallicity, orbital separation, eccentricity, rotations)



- « Black box » method
- Needs a training dataset anyway

Neural network



Final binary black hole Y

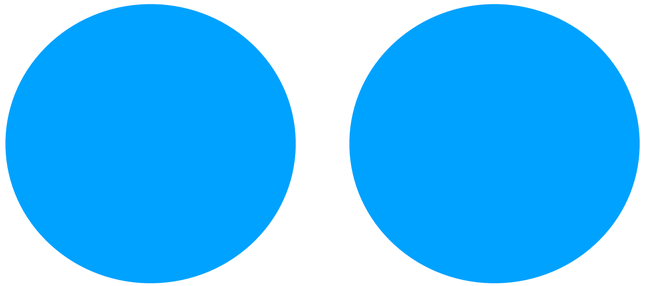
Y = (Masses, spins, orbital parameters)

- Efficient to evaluate once trained
- Differentiable by design
- Suited for Bayesian inference pipelines

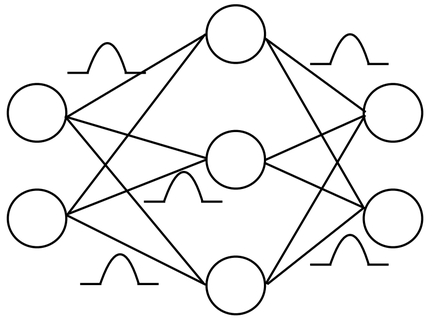
My PhD in a nutshell

Initial binary properties X

X = (Masses, mettalicity, orbital separation, eccentricity, rotations)



Bayesian neural network



Final binary black hole Y

Y = (Masses, spins, orbital parameters)

- « Black box » method
- Needs a training dataset anyway

Bayesian deep active learning

- Predictive uncertainty quantification
- Choose training dataset based on low confidence samples (Active learning)
- Automatic process

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