

Never seen before - *Gaia* binaries and the challenges for
the binary evolution models

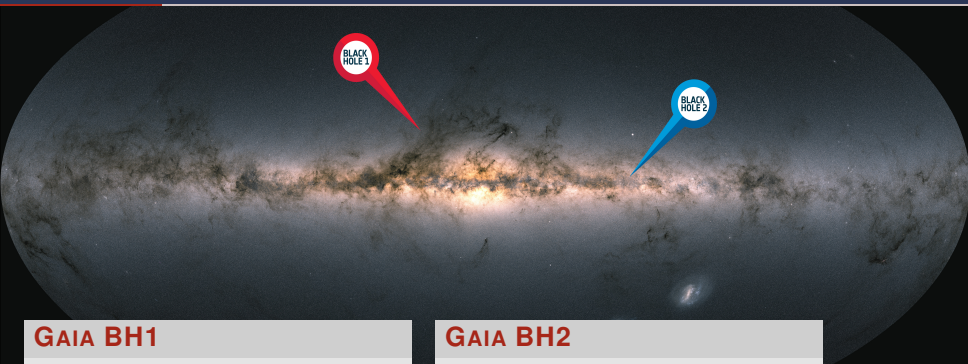
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CAMK PAN



THE *Gaia* PUZZLING BINARIES



GAIA BH1

- $\sim 9 M_{\odot}$ BH + $\sim 1 M_{\odot}$ MS
- $P_{\text{orb}} \sim 186$ days
- $e \sim 0.45$
- $v_{\text{sys}} \sim 71$ km/s
- $d \sim 460$ pc : the nearest BH ever found

GAIA BH2

- $\sim 9 M_{\odot}$ BH + $\sim 1 M_{\odot}$ RG
- $P_{\text{orb}} \sim 1300$ days
- $e \sim 0.52$
- $v_{\text{sys}} \sim 34$ km/s
- $d \sim 1.16$ kpc : the second-nearest BH known



THE BINARY EVOLUTION OF GAIA BHs

THE PREVAILING EVOLUTION SCENARIO CANDIDATES

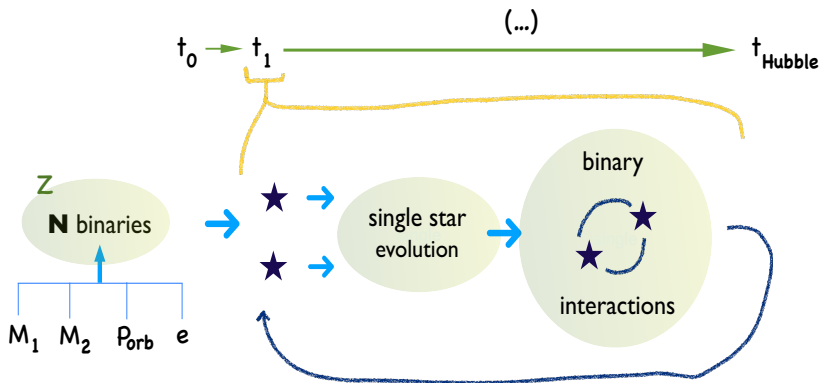
- The isolated binary evolution
- The dynamical interactions in open clusters

THE ALTERNATIVE SCENARIOS

- BH progenitor that never becomes a supergiant
- Formation in hierarchical triple

POPULATION SYNTHESIS CALCULATIONS

StarTrack



- properties of different binary populations
e.g. XRBs, Gaia BH-like
- endpoint of their evolution,
e.g. GWs

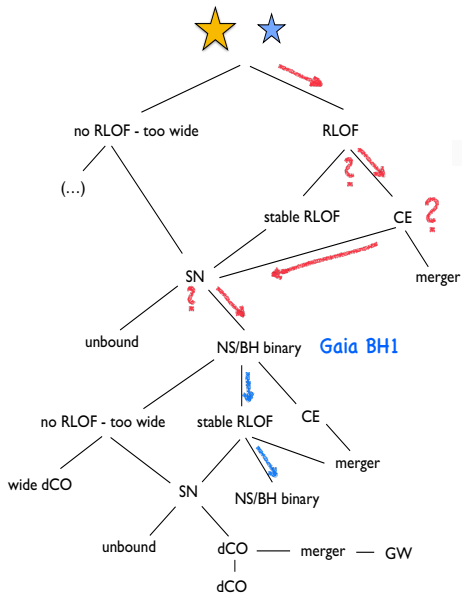


- LIGO/VIRGO/KAGRA
- LISA
- EM observations

WHAT WE'VE LEARNT ABOUT GAIA BH1 AND GAIA BH2 FROM SIMULATIONS

- The binaries matching Gaia BH1 and Gaia BH2 can be formed through isolated binary evolution (IBE)
- The formation rates of Gaia BH-like systems through IBE and through dynamical interactions in open clusters are comparable ($\sim 10^{-6} M_{\odot}^{-1}$)
- Gaia BH1(BH2) may be the progenitors of the long period low mass X-ray binaries with outburst recurrence times of order of tens of years
- Gaia BH1: 94% systems form with BH spin misaligned with binary angular momentum by no more than 40° (median $\theta \sim 10^{\circ}$)
- Gaia BH2: form if the natal kick lower than < 42 km/s is directed close to the orbital plane ($\pm 15^{\circ}$)

THE EVOLUTION OF GAIA BH1 - IBE



- Roche Lobe Overflow (RLOF) - stability criteria
- Common Envelope (CE) phase - parameterization
- Supernova (SN) - rapid/delayed engine, natal kicks distribution

SUMMER PROJECT

SUBJECT OF THE RESEARCH: GAIA NS1

- $\sim 1.9 M_{\odot}$ NS + $\sim 0.79 M_{\odot}$ star
- $P_{\text{orb}} \sim 731$ days
- $e \sim 0.124$
- Age ~ 12.5 Gyr

MAIN OBJECTIVE

- Can Gaia NS1-like binaries form through IBE channel?
 - Mass transfer stability criteria
 - CE ejection efficiency
 - Constrains on natal kick

TOOLS

- StarTrack