Extragalactic Wanderers: Migration Of Compact Binaries From Their Host Galaxies

UNIVERSITY OF LEICESTER

S. Mandhai[1], N. Tanvir[1], G. Lamb[1], J. Bray[2,3], C. Nixon[1]

[1] Department of Physics and Astronomy, University of Leicester, University Road, LE1 7RH

[2] Department of Physical Sciences, Robert Hooke Building, Kents Hill, Milton Keynes MK7 6AA

[3] Department of Physics, University of Auckland, Private Bag 92019, Auckland, New Zealand

Overview:

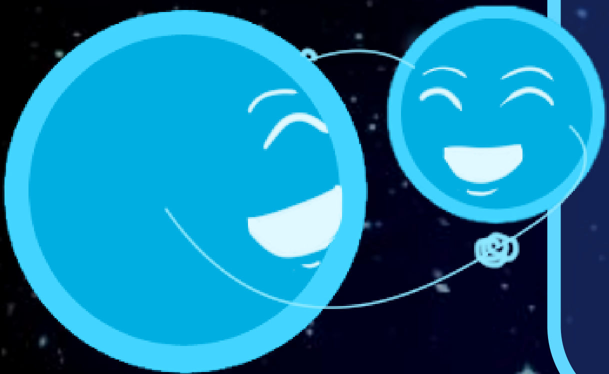
- Compact binaries can consist of a combination of Neutron Stars and Black Holes. Upon merging, they can:
  - Distort space-time, resulting in Gravitational Waves.
  - Produce beams of highly energetic radiation known as, Short-duration Gamma-Ray Bursts.
- Identifying the parent galaxy of these events is difficult.
- During their formation, these binaries can be ejected from their host galaxy due to the supernova of their progenitors.
- Simulating the evolution and migration of these binaries enable us to understand the host galaxy properties and the observed offsets of short-duration gamma-ray bursts.
- Between 40-45% of binaries escape their host galaxy.
- Future missions and surveys will test and improve predictions made in this analysis.

Hi, I'm Neutros!

I'll be your guide throughout this poster.

If you have any further questions regarding the work presented here, please send an e-mail to:

SFM13@leicester.ac.uk



What Are Compact Binaries? What Makes Them Special?

- Dense remnants of two stars born with mass $> 8\ M_{sun}$, after they die.
- A binary system that can consist of a combination of Neutron Stars (NS), and Black-Holes (BH).
- Capable of distorting space-time and creating Gravitational Waves (GWs).
  - GWs provide unprecedented insight into the properties of NS and BH objects.
- Systems with at least one NS may produce electromagnetic counterparts such as Short-duration Gamma-Ray Bursts (SGRBs) and Kilonovae (KN) (results in the synthesis of heavy elements such as gold, and platinum) upon merging.
- The merger of two neutron stars with coincident GW (GW170817) and SGRB (GRB 170817A) detections marked the start of the multi-messenger era in astrophysics!

The Associativity Issue:

- SGRB detections are plentiful.
- A localised SGRB indicates the final position of the progenitor compact binary.
- Very few events have a known galaxy of origin (the host galaxy).
- Host galaxies can be faint/distant and therefore, difficult to identify.
- Compact binaries may get kicked out of their host galaxy.
- The distance between a nearby galaxy and the merger can be determined.

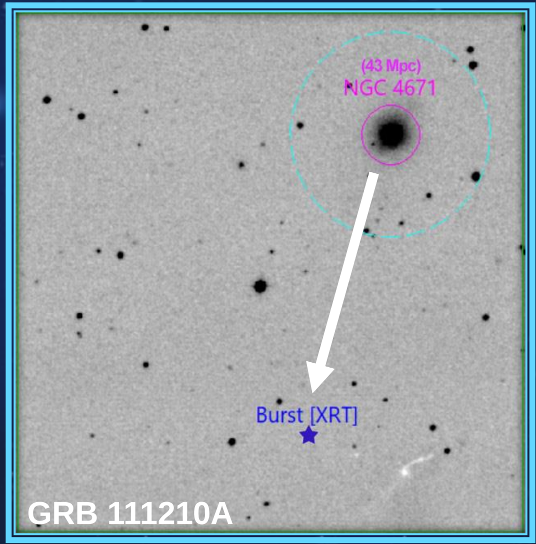


Figure 1: [Example] The site of a short-duration gamma-ray burst and a nearby host candidate.[1]

Generating Predictive Models Using Simulations:

- Using simulated binaries and galaxies, we:
  - Seed binaries into galaxies.
  - Evolve their orbits until they merge (see Figure 2).
  - Extract the property of the host galaxy, and position of the binary at the point of coalescence.
- We consider:
  - The initial environment of the host galaxy and whether it can form a compact binary.
  - The mass of the host galaxy may affect the migration of the binary.
  - The natal kick velocities imparted by supernovae following the evolution of the progenitor stars in the binary system.

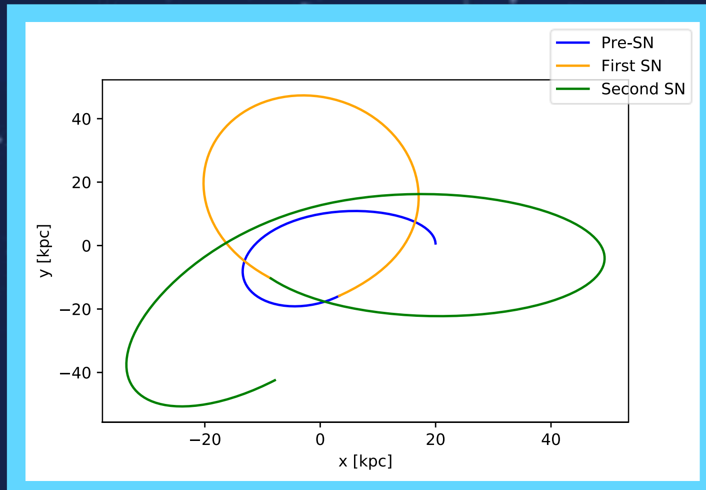
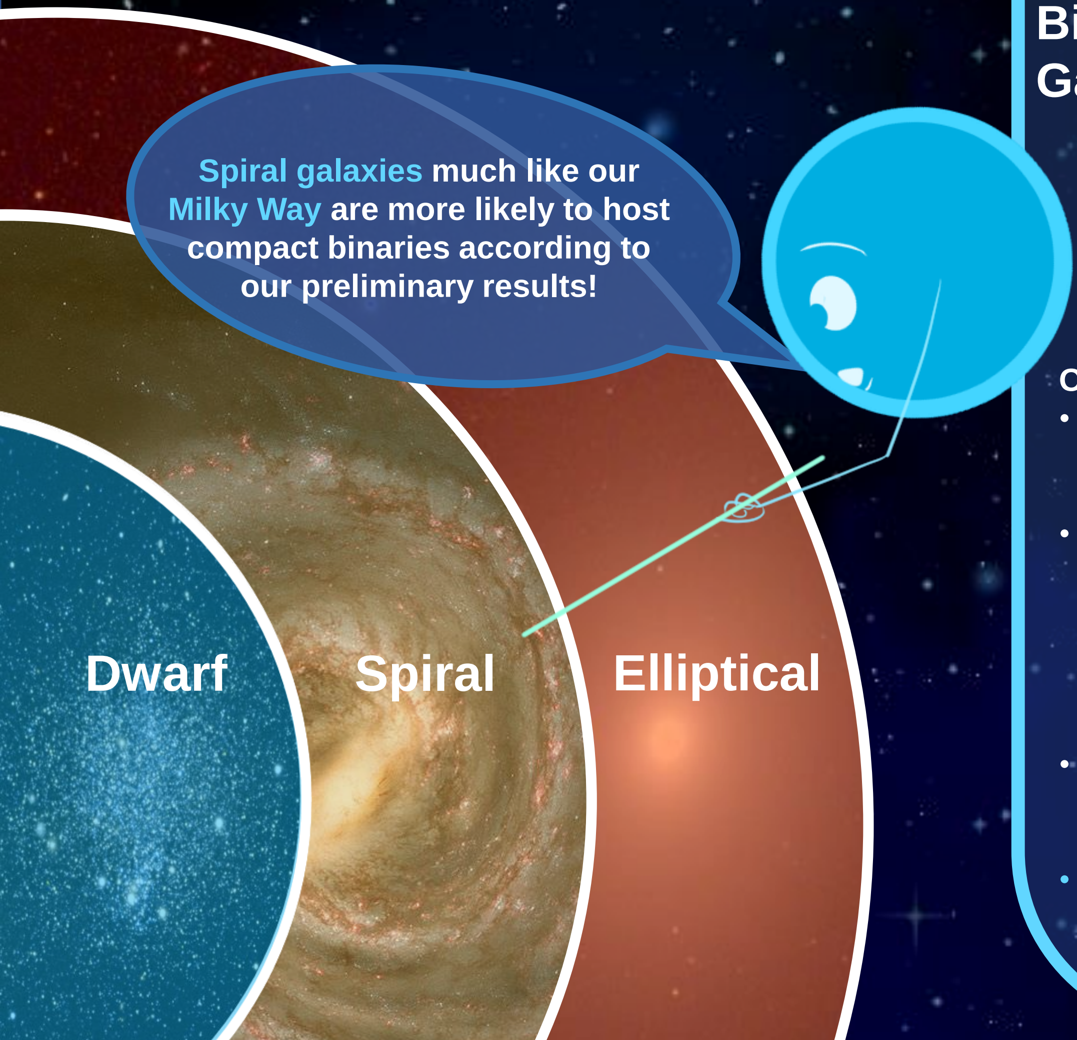


Figure 2: An example simulation of an orbital path (in the x-y plane) that a compact binary may take if it receives two strong supernova (SN) kicks.
Note: 1 kpc ≈ 3000 Light Years



Binary Migration Relative To Their Host Galaxies:

- Globally (see Figure 3), these systems tend (up to 50%) to merge within a projected distance (known as the impact parameter) of ~(few) 10 ly from the centre of their host galaxy.
- (Refer to the left) Binaries may merge between the dashed regions depending on the type of host galaxy (Dwarf, Spiral, Elliptical).
  - The solid lines indicate the likely migration distance.

Our results show:

- Binaries are more likely to travel further from less massive galaxies.
- Depending on the type of binary (NS-NS or BH-NS), 40-45 % (non-negligible) of systems could be ejected from their host galaxies entirely.
- A small fraction of systems have impact parameters of >1000 ly.
- Potential SGRBs produced by these systems would be considered host-less.

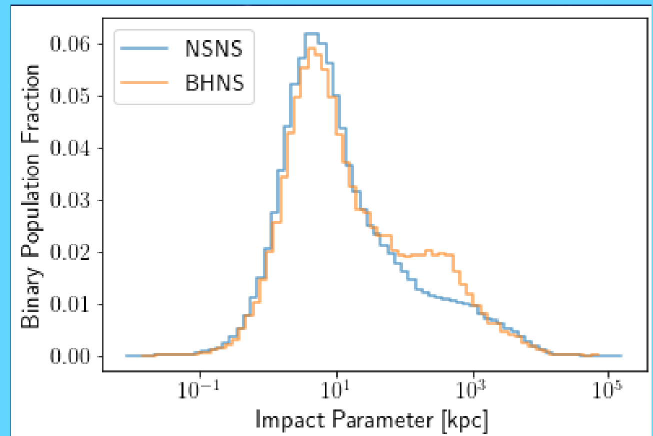
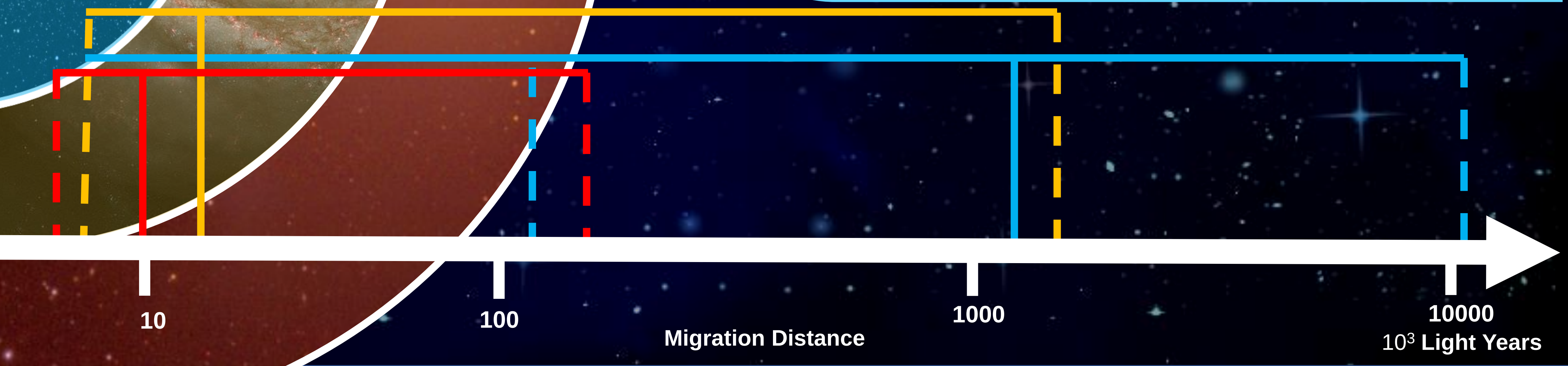


Figure 3: The global distribution of the impact parameters obtained for the NS-NS and BH-NS systems in our analysis.

Note: 1 kpc ≈ 3000 Light Years



Research Applications:

The work presented in this poster highlights the typical host galaxy type and migrated distances that we expect to be representative of a vast population of NS-NS and BH-NS compact binaries.

Future missions and surveys (see Figure 4) will:

- Make more SGRB detections at greater distances.
- Allow us to uncover more distant galaxies, enabling more successful associations with SGRBs.
- Observe more compact binaries occurring at greater distances using gravitational waves.
- Potential for more coincident GW detections with an SGRB counterpart

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TRANSIENT HIGH ENERGY SKY AND EARLY UNIVERSE SURVEYOR

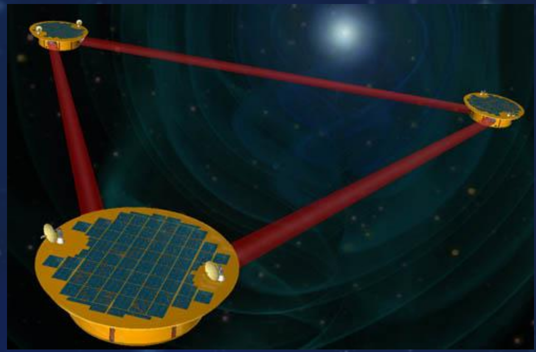

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Figure 4: An example selection of the missions expected within the next few decades. [Top] Theseus; [Bottom Left] Laser Interferometer Space Antenna (LISA); [Bottom Right] Einstein Telescope

Key Points:

- We seeded synthetic NS-NS and BH-NS binaries into simulated galaxies.
- A large fraction of binaries are produced in galaxies that are much like our Milky Way.
- For each system, we trace the evolution of their orbit.
- Generally, up to 50% of binaries merge within ~ (few) 10 ly.
- 40-45% of NS-NS and BH-NS systems are ejected from their host galaxy. Potential SGRBs would appear to have no host galaxy if observed.
- A small fraction of systems can travel > 1000 ly from the centre of their host galaxies.

References:

A. [ESO] Phoenix Dwarf Galaxy Image
B. [NASA] Messier-49 Image
C. [Universe Today] Milky Way Image
D. [THESEUS] Thesus Logo
E. [ET-GW] Einstein Telescope Logo
F. [NASA] LISA Visualisation
1. Mandhai, Soheb, et al. "The rate of short-duration gamma-ray bursts in the local universe." *Galaxies* 6.4 (2018): 130.

Acronym Box:

NS-NS – Neutron Star Binary
BH-NS – Black Hole and Neutron Star Binary
BHBH – Black Hole Binary
GW – Gravitational Wave
SGRB – Short Duration Gamma-Ray Burst
KN – Kilonova(e)
EM – Electromagnetic
SN – Supernova(e)

E-mail: SFM13@leicester.ac.uk