HEAVY DOUBLE NEUTRON STARS: BIRTH, MIDLIFE & DEATH

Shanika Galaudage[1,2], Christian Adamcewicz[1,2], Xingjiang Zhu[3], Simon Stevenson[2,4], Eric Thrane[1,2]

1 School of Physics and Astronomy, Monash University, Clayton VIC 3800, Australia; 2 OzGrav: The ARC Centre of Excellence for Gravitational Wave Discovery, VIC, Australia;
3 Advanced Institute of Natural Sciences, Beijing Normal University at Zhuhai, People' s Republic of China; 4 Centre for Astrophysics and Supercomputing, Swinburne University of Technology, Hawthorn, VIC 3122, Australia

INTRODUCTION

We develop a model to **determine the birth mass distribution of double neutron stars (DNS)** from radio and gravitational wave (GW) observations. We also consider how to **account for the unusual mass of GW190425**, where a possible explanation for lack of massive DNS in radio is that they are fast-merging (e.g. via unstable case-BB mass transfer [1], Fig. 1).

BIRTH
link between radio & GWs

MIDLIFE
what we observe in radio

DEATH
what we observe in GWs

THE BIRTH DISTRIBUTION OF DOUBLE NEUTRON STARS

Standard DNS formation scenario: a first-born **recycled** neutron star (NS) sped up from accretion and a second-born **slow** NS. We assume the following model:

Birth mass distribution:
- double Gaussian for recycled NS [2]
- double Gaussian for slow where **high-mass peak is motivated by fast-merging DNS**

Formation rate densities:
- uniform in cosmic time for Milky Way
- Madau-Dickinson star formation rate density for extra-galactic populations

To connect the birth population to the radio & GW populations we need to consider the delay-time distribution: **slow-merging channel** = log uniform 30 Myr to age of Milky Way; **fast-merging channel** = 5 to 500 Myr

Let's evolve this birth population forwards in time to merger...

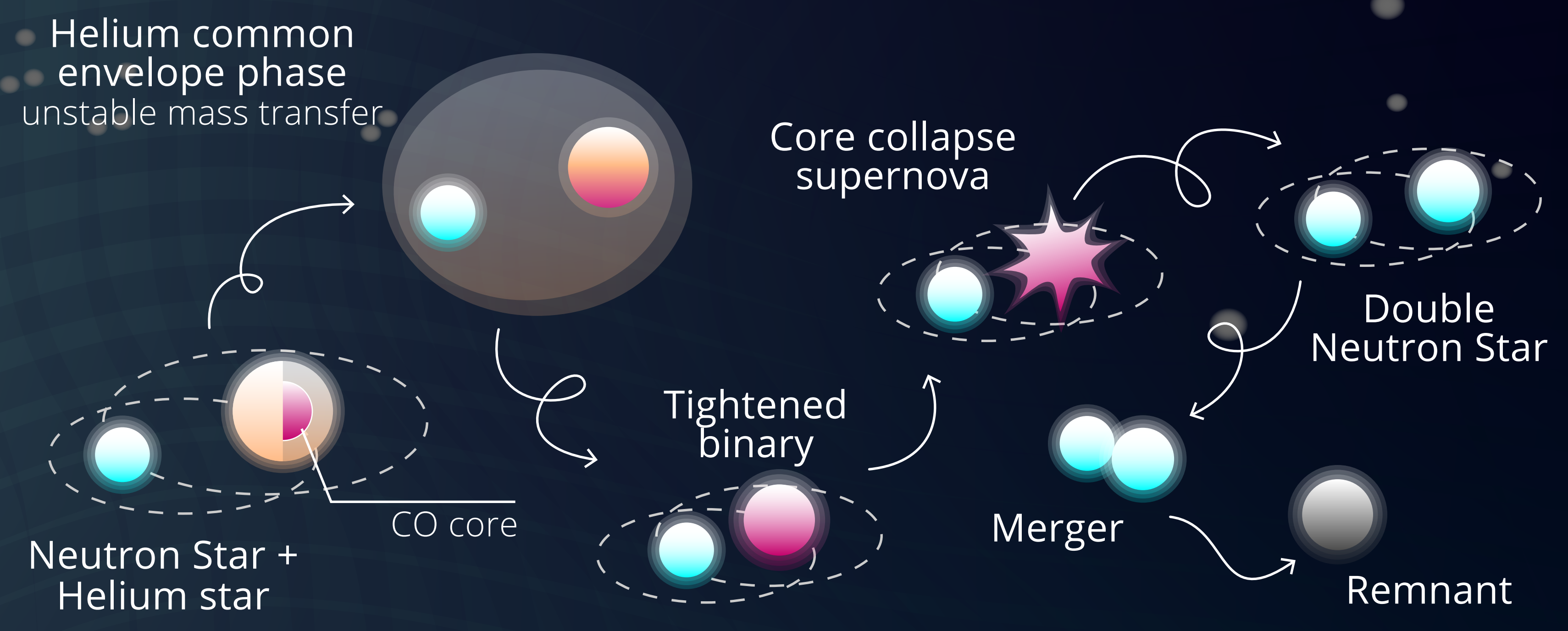

FIGURE 1: Diagram of unstable Case BB evolution of a DNS system.

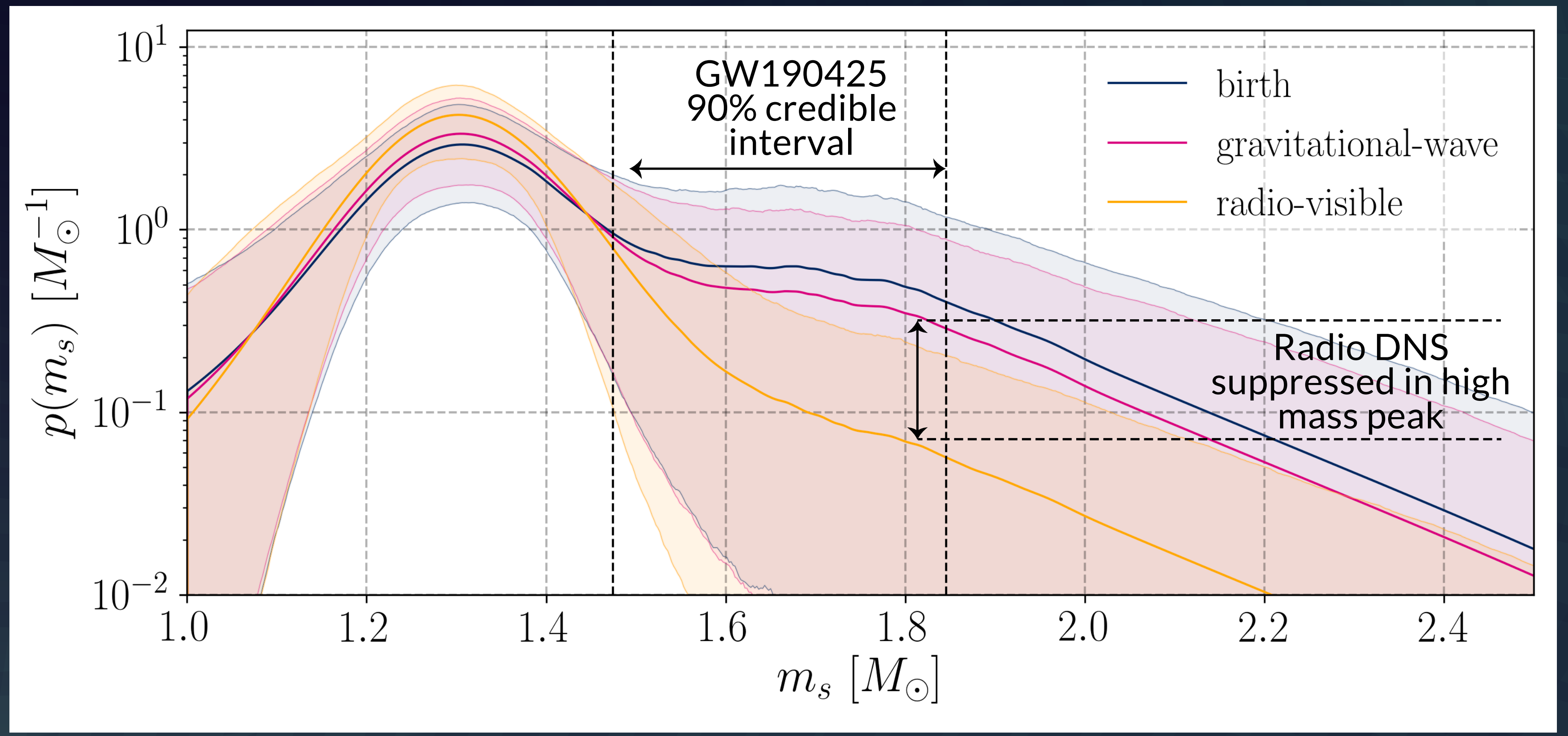

FIGURE 2: Slow NS mass distribution for birth (navy) radio-visible (yellow) and GW (pink) populations for hierarchical inference study including 2 NS mergers [3] and 12 radio DNS [2]

EVOLVING THE DNS MASS DISTRIBUTION

GW population: With DNS birth rate & delay-time distribution we can calculate the merger rate for the slow & fast merging channels

$$R_m(t) = \int_0^t dt_b R_b(t_b)\, \pi(t - t_b) \qquad N_r(t) = \int_0^t dt' \left(R_b(t') - R_m(t')\right) \epsilon(t')$$

Radio-visible population: From the population that has not merged we can determine the number of radio-visible binaries using the birth rate, merger rate and the fraction of radio binaries beamed.

$$\zeta_{\rm GW} = R_m(\text{slow})/R_m(\text{fast})$$
$$\zeta_{\rm radio} = N_r(\text{slow})/N_r(\text{fast})$$

Relative fraction of DNS evolving in each channel (i.e. weights for peaks in slow mass distribution)

For our analysis we start with the radio and GW populations and wind the clock back. This gives us the mass distribution in Fig. 2

CONCLUSIONS

We proposed a framework for linking the distribution of DNS at birth, mid-life (radio), and death (GWs). We find mild evidence for the fast-merging channel hypothesis; GW190425 is not a clear outlier from the Galactic population. Assuming the fast-merging hypothesis:

- radio DNS suppressed by a factor of ~4-74 in high mass peak
- 8-79% of DNS born are fast-merging

This work has been published in **ApJL** and is available on **arXiv**

REFERENCES

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