Quantifying the evidence against a mass gap between black holes and neutron stars

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Key terms :

Neutron stars :

Formed from the collapse of the iron core inside of stars at the end of their life. (~8-25 Solar Masses)

Maximum mass : ~2.2-2.6 Solar masses

Black holes :

Also formed from death of stars, but only the biggest ones (>25 Solar masses)

Minimum mass : ~4-5 Solar masses.

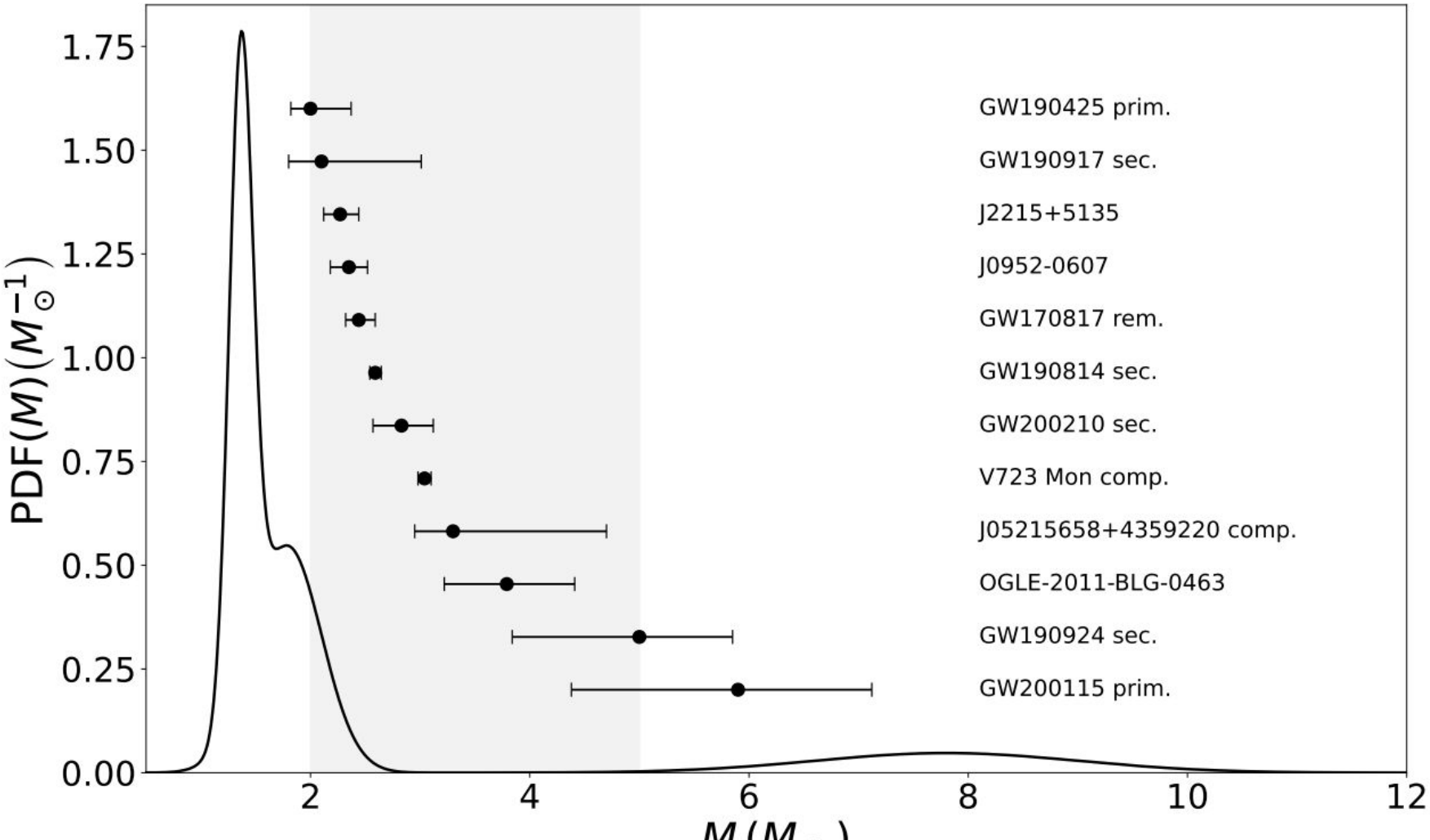

1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
PDF(M)(M⊙⁻¹)
2
4
6
8
10
12
M (M⊙)
GW190425 prim.
GW190917 sec.
J2215+5135
J0952-0607
GW170817 rem.
GW190814 sec.
GW200210 sec.
V723 Mon comp.
J05215658+4359220 comp.
OGLE-2011-BLG-0463
GW190924 sec.
GW200115 prim.

Table 1. Mass Distributions for the 12 New Objects Used in This Work

Name	M ($M_\odot$)	Reference
GW 200115 prim.	$AN(5.9, 1.22, 1.52)$	The LIGO Scientific Collaboration et al. (2021b)
GW 190924 sec.	$AN(5, 0.85, 1.16)$	Abbott et al. (2021b)
OGLE-2011-BLG-0463 (DW)	$AN(3.79, 0.62, 0.57)$	Lam et al. (2022)
OGLE-2011-BLG-0463 (EW)	$AN(2.15, 0.67, 0.54)$	Lam et al. (2022)
2MASS J05215658+4359220 comp.	$AN(3.3, 1.4, 0.35)$	Thompson et al. (2019)
V723 Mon comp.	$N(3.04, 0.06)$	Jayasinghe et al. (2021)
GW 200210 sec.	$AN(2.83, 0.29, 0.26)$	The LIGO Scientific Collaboration et al. (2021b)
GW 190814 sec.	$N(2.59, 0.05)$	Abbott et al. (2020)
GW 170817 rem.	$AN(2.44, 0.15, 0.12)$	Shibata et al. (2019)
PSR J0952-0607	$N(2.35, 0.17)$	Romani et al. (2022)
PSR J2215+5135	$AN(2.27, 0.17, 0.15)$	Linares et al. (2018)
GW 190917 sec.	$AN(2.1, 0.91, 0.3)$	The LIGO Scientific Collaboration et al. (2021a)
GW 190425 prim.	$AN(2, 0.37, 0.18)$	Abbott et al. (2021b)

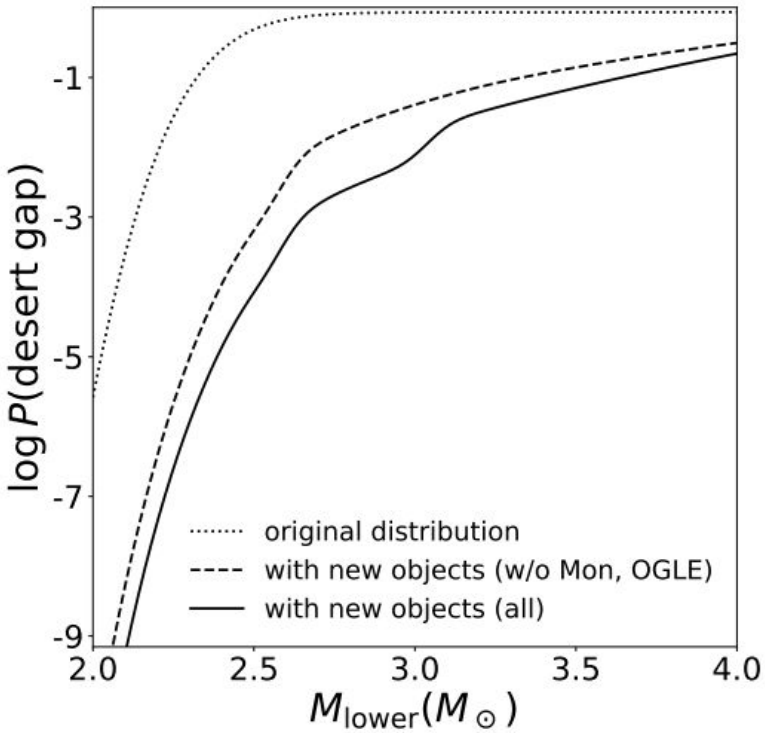
Analysis methods :

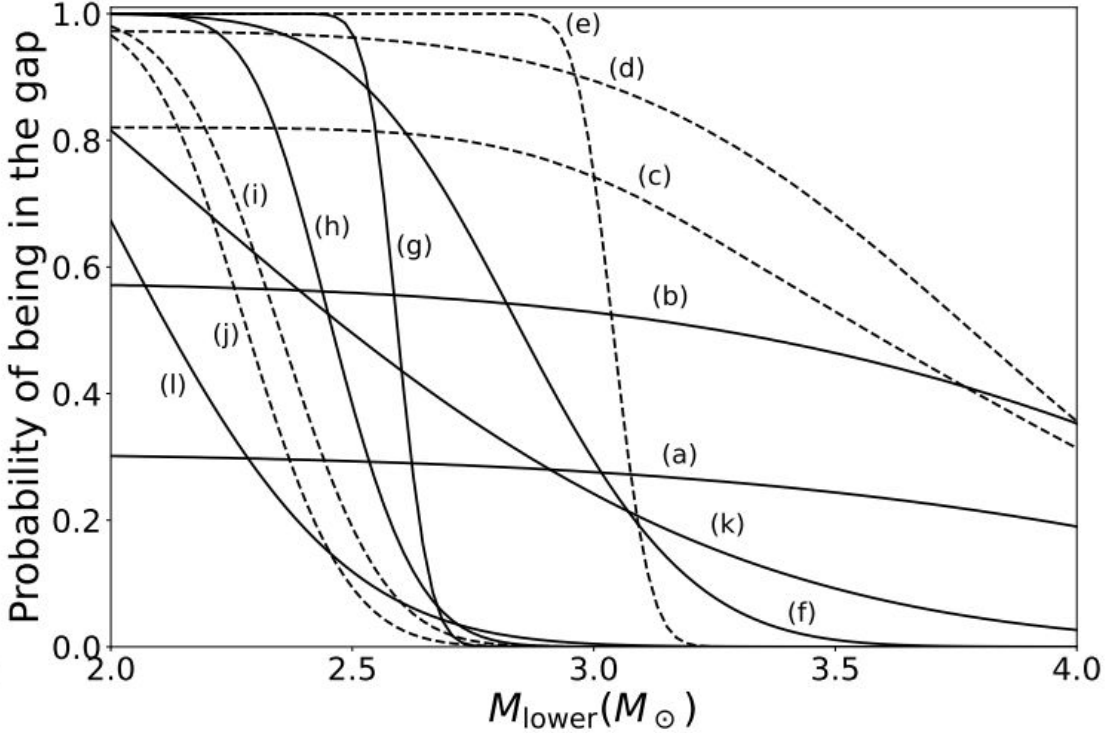
Joint probability and cumulative distribution function test

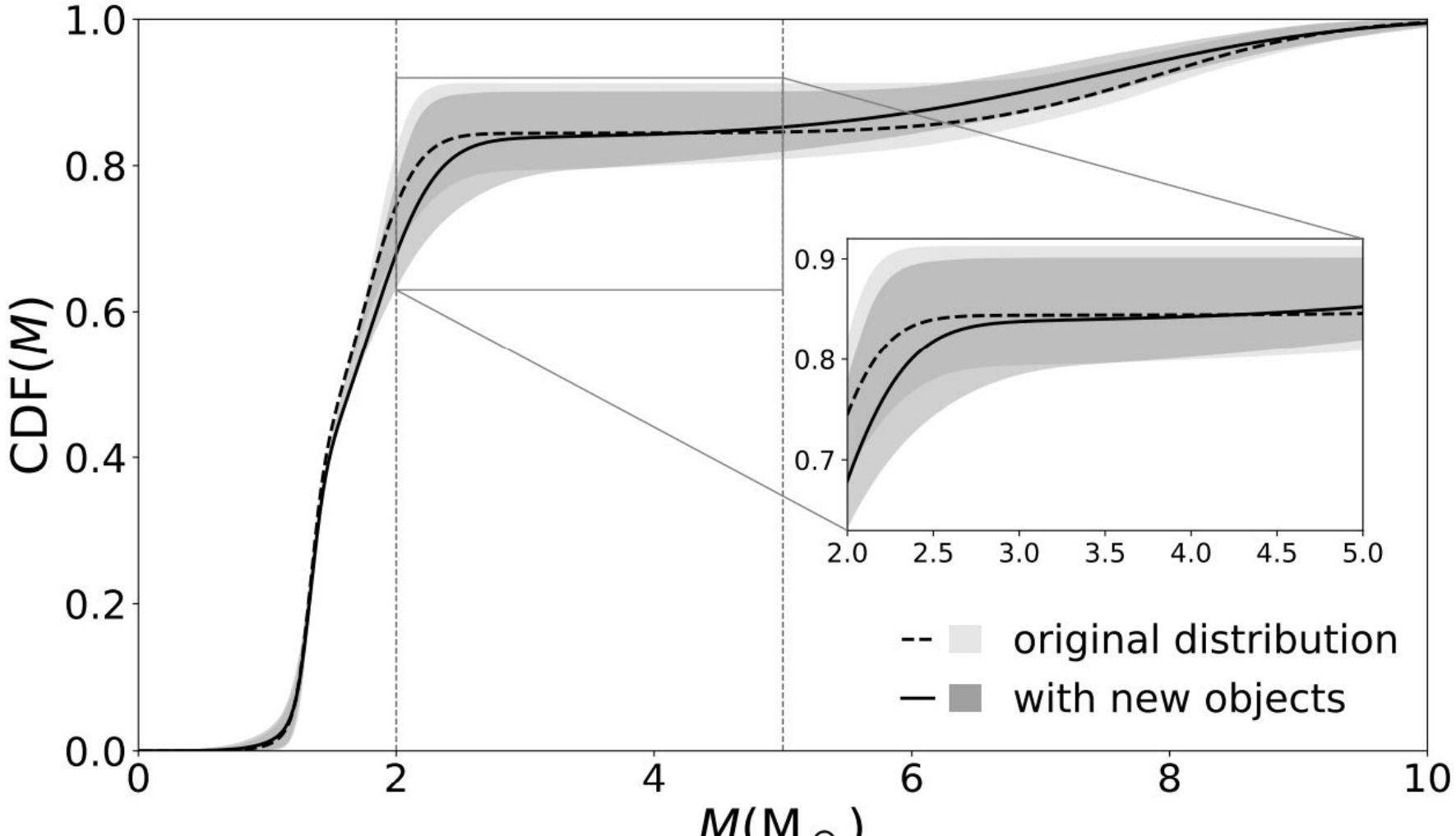
Used to determine the probability of an absolute gap below 4 Solar masses

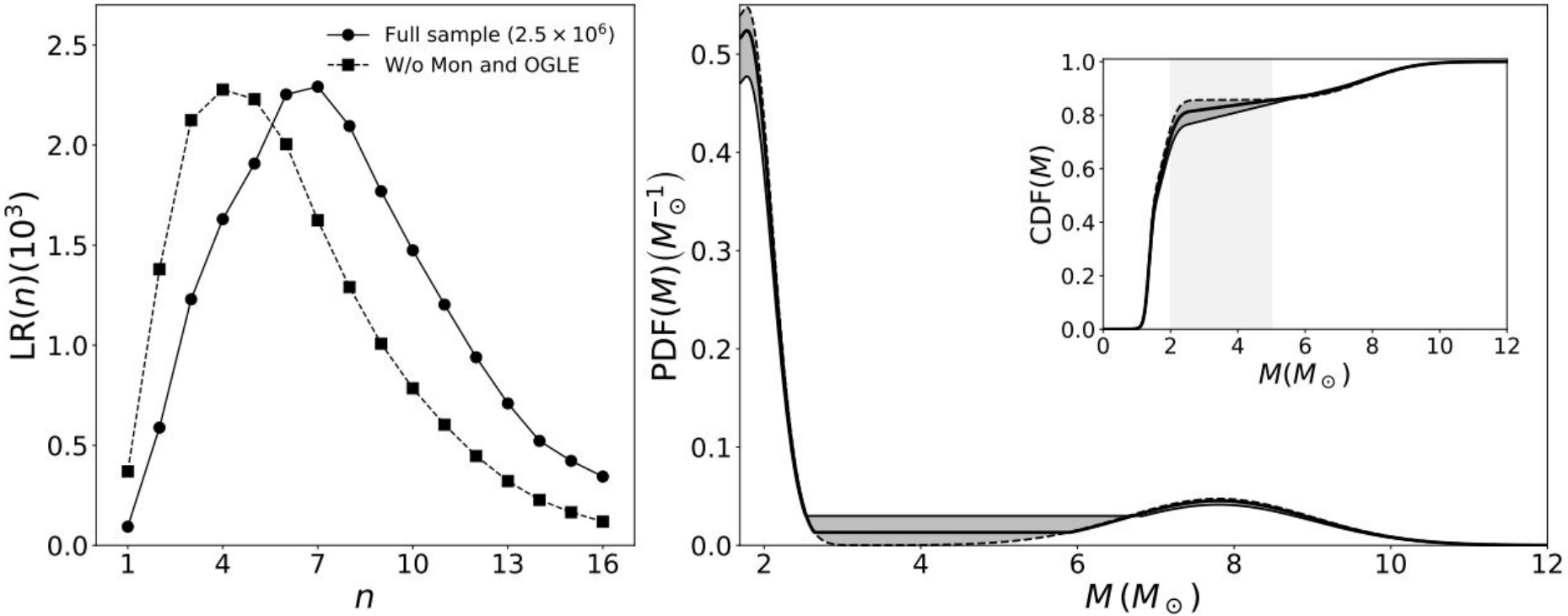
Likelihood ratio test

Compares the mass distribution of the surveyed objects against a plateau between the mass distribution of the Neutron stars and Black holes, then determine how they prove or disprove the gap theories.


log P(desert gap)
-1
-3
-5
-7
-9
2.0
2.5
3.0
3.5
4.0
$M_{\rm lower}(M_\odot)$
original distribution
with new objects (w/o Mon, OGLE)
with new objects (all)


Probability of being in the gap
1.0
0.8
0.6
0.4
0.2
0.0
2.0
2.5
3.0
3.5
4.0
$M_{\rm lower}(M_\odot)$
(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
(i)
(j)
(k)
(l)


1.0
0.8
0.6
0.4
0.2
0.0
CDF(M)
0
2
4
6
8
10
M(M⊙)
0.9
0.8
0.7
2.0
2.5
3.0
3.5
4.0
4.5
5.0
original distribution
with new objects


Full sample (2.5×10^6)
W/o Mon and OGLE
LR(n)(10^3)
n
PDF(M)($M_\odot^{-1}$)
$M\,(M_\odot)$
CDF(M)
$M(M_\odot)$

Summary

Existence of a gap between Neutron stars and Black holes have long been proposed

Using newly obtained observational data, this paper disproved the existence of an absolute gap, instead favouring the existence of a relative gap

More research is needed to determine the exact shape of the distribution, as well as whenever it is just a relative gap or no gap at all.