Follow-up and spectroscopy of GW alerts with GTC/OSIRIS, BOOTES and the science case of Intermediate Mass Black Holes

M. D. Caballero-Garcia (ASU-CAS, Prague, CR),
A. J. Castro-Tirado (IAA-CSIC, Spain),
on behalf of a larger collaboration

Gran Telescopio de Canarias (GTC)

Telescope of D=10.4 m diameter located at Canary Islands (Spain).

GTC/OSIRIS

- **OSIRIS** (**O**ptical **S**ystem for **I**maging and low-Intermediate-**R**esolution **I**ntegrated **S**pectroscopy) is an imager and spectrograph for the optical wavelength range, located in the Nasmyth-B focus of GTC.
- Apart from the *standard broad-band imaging and long-slit spectroscopy*, it provides additional capability such as the narrow-band tunable filters imaging, charge-shuffling and multi-object spectroscopy.

Program with GTC/OSIRIS

- After a LIGO-VIRGO trigger and after ensuring detection of a counterpart candidate at X-ray, optical-NIR, or radio wavelengths, with an angular accuracy no worse than few arc-seconds (~1” for optical/radio detections and few arc-sec for X-ray detection with soft X-ray cameras like Swift /XRT).
- We take spectra with OSIRIS and gather imaging of this candidate at several epochs to identify its nature, measure its redshift and follow its time evolution.
- OSIRIS is an optimal instrument because of its flexibility and wide wavelength range, as we have already proved (in the case of OSIRIS) **following up one of the candidates for the second LIGO alert in Dec. 2015 (Castro-Tirado et al. 2016).**
- Of the several GTC spectra that we will take, one will be acquired as soon as possible after notification (via internal communication) of a counterpart candidate detection through imaging. Additional spectra will be taken the following 5-10 days, depending on the results of the first visit, to establish spectral evolution and/or provide a spectral template for subtraction.
- Follow-up imaging in optical with GTC and other telescopes will also start, with observations at several epochs depending on the level and behaviour.

Related publications

- Localization and broadband follow-up of the gravitational wave transient GW150914, Abbott, B. P. et al., 2016, ApJ, 826, L13
- LIGO/Virgo G211117: 10.4m GTC follow-up of PS15dpn, Castro-Tirado, A. J. et al., 2016, GCNC, 19258
- LIGO/Virgo G268556: 10.4m GTC spectroscopic observations of iPTF17fs, Castro-Tirado, A. J. et al., 2017, GCNC, 20409
- Multi-messenger Observations of a Binary Neutron Star Merger", Abbott, B.P. et al. 2017 ApJL 848, 12
- Spectroscopic identification of r-process nucleosynthesis in a double neutron-star merger, Pian, E. et al. Nat 551, 67
- A peculiar low-luminosity short gamma-ray burst from a double neutron star merger progenitor, Zhang, B.-B-. et al. 2017, Nat Co. 9, id.447.

Burst Optical Observer and Transient Exploring System (BOOTES)

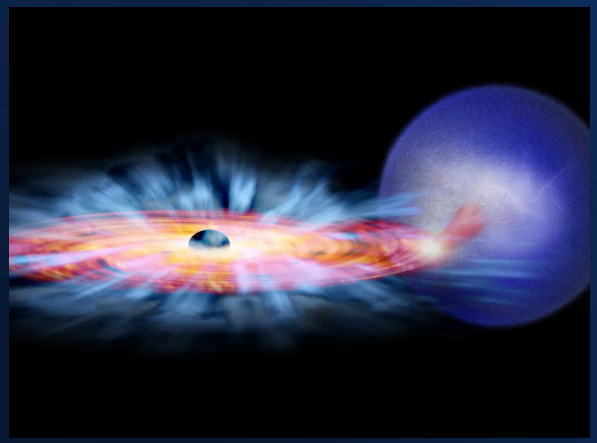
A world wide Network of Robotic Telescopes.

- Located worldwide (B1-2@Spain, B3@New Zealand, B4@China, B5@Mexico).
- Small (D=60 cm) and autonomous telescopes.
- For the study of the fast variability from sources of astrophysical origin (e.g. GRBs, transients,...).
- Also a wide-field instrument at B1@Huelva (which has a 5º x 5º FOV).
- **B5/JGT telescope detected the GW170817 counterpart (GCNC#21624)**.

Burst Optical Observer and Transient Exploring System (BOOTES)

Intermediate Mass Black Holes

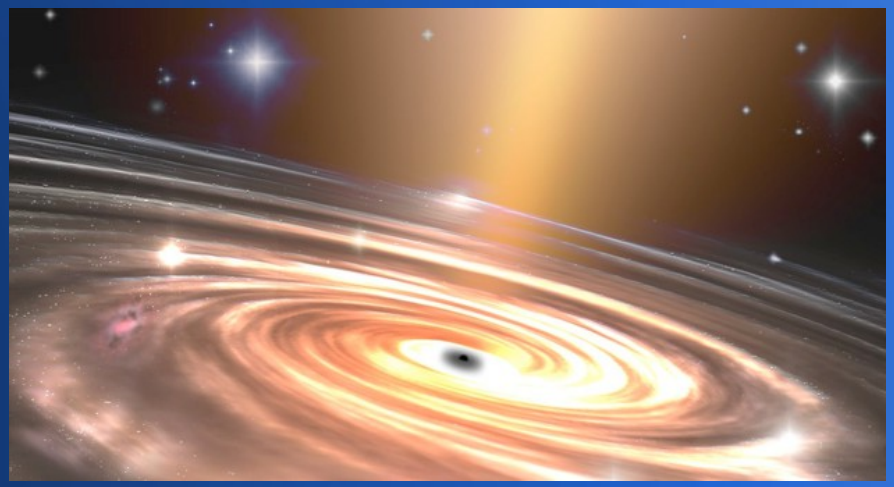
- *First claim of EM counterparts of InterMediate-Mass Black Holes* (IMBHs; $M_{BH} \geq 10^2$-$10^4\ M_\odot$; Colbert & Mushotzky, 1999, so-called ULXs).
- The existence of these ULXs-IMBHs is controversial only few cases recently confirmed (ESO 243-49 HLX1, Farrell et al. 2011; see Sutton et al. 2012 for a few more candidates). See Mezcua+17 for many IMBH candidates with $M_{BH} \geq 10^3$-$10^4\ M_\odot$



Stellar-mass Black Hole (BH); ***$M_{BH} \leq 10\ M_\odot$***

IMBHs (Madau & Rees, 2001)

?



Supermassive Black Hole (AGN); ***$M_{BH} \geq 10^6\ M_\odot$***

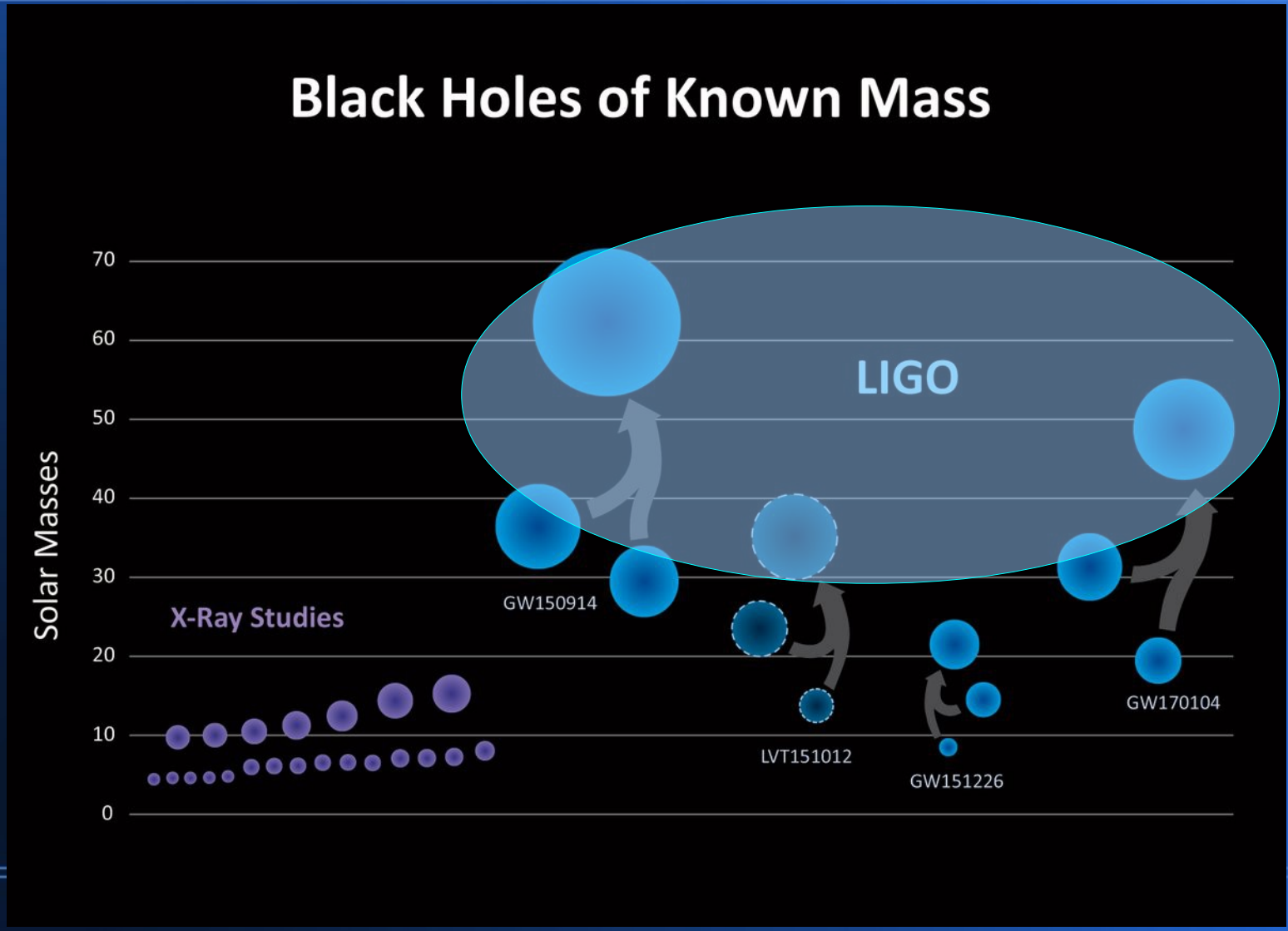
After 20 years: have we have found the EM couterpart of the IMBHs proposed to exist as cosmological seeds of current galaxies by

Madau & Rees (2001)

?

Very likely not

Gravitational Waves: a new window to the Universe



"Elusive" IMBHs ($M_{BH} \geq 30\text{-}10^2 M_\odot$)

Gravitational Waves: a new window to the Universe

- BHs do not necessarily have EM counterpart (i.e. they are “black”).
- Only BHs interacting with another star and/or clouds of gas can have EM counterpart.
- **The EM counterpart of BHs with masses of $M_{BH} \geq 30\text{-}10^2\ M_\odot$ has never been detected so far.**
- These invisible/ “elusive” BHs ($M_{BH} \geq 30\text{-}10^2\ M_\odot$) are now systematically being observed by GW-detectors (LIGO, VIRGO,...).
- The discovery of BHs in the mass-range of $M_{BH} \geq 30\text{-}10^2\ M_\odot$ is unexpected (they are “black” and they have been detected in this mass-range with GWs).
- They might constitute a significant part of the enigmatic “dark matter” (?).

Acknowledgements

Financial support by:

1st) The European "Seventh Frame-work Programme (FP7/2007-2013) under grant agreement # 312789".

Period of the project's realization 1.1.2013 – 31.12.2017

2nd) GA CR grant 18-00533S.

Period of the project's realization 1.1.2017 – 31.12.2020