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The formation of binary stellar black holes

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I will present the current theoretical models and the multiple strands of observational evidence for the formation of binary stellar black holes, the first sources of gravitational waves detected by LIGO. It is believed that stellar black holes (BHs) can be formed in two different ways: Either a massive star collapses directly into a BH without a supernova (SN) explosion, or an explosion occurs in a proto-neutron star, but the energy is too low to completely unbind the stellar envelope, and a large fraction of it falls back onto the short-lived neutron star (NS), leading to the delayed formation of a BH. Theoretical models set progenitor masses for BH formation by implosion, namely, by complete or almost complete collapse, but observational evidences have been elusive. Here are reviewed the observational insights on BHs formed by implosion without large natal kicks from: (1) the kinematics in three dimensions of space of five Galactic BH X-ray binaries (BH-XRBs), (2) the diversity of optical and infrared observations of massive stars that collapse in the dark, with no luminous SN explosions, possibly leading to the formation of BHs, and (3) the sources of gravitational waves produced by mergers of stellar BHs so far detected with LIGO. The multiple insights of BH formation without ejection of a significant amount of matter and with no natal kicks obtained from these different areas of observational astrophysics, and the recent observational confirmation of the expected dependence of BH formation on metallicity and redshift, are qualitatively consistent with the high merger rates of binary black holes (BBHs) inferred from the first detections with LIGO.

Auteur principal: Dr MIRABEL, Felix (CEA-France & CONICET-Argentina)

Orateur: Dr MIRABEL, Felix (CEA-France & CONICET-Argentina)

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