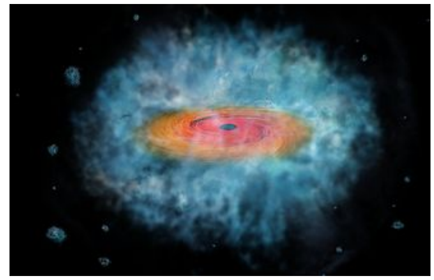
WIKIPEDIA

Direct collapse black hole

Direct collapse black holes are high-mass black hole seeds,[2][3][4][5] putatively formed within the redshift range $15 < z < 30$,[6] when the Universe was about 100-250 million years old. Unlike seeds formed from the first population of stars (also known as Population III stars), direct collapse black hole seeds are formed by a direct, general relativistic instability. They are very massive, with a typical mass at formation of ~$10^5\ M_\odot$.[3][7] This category of black hole seeds was originally proposed theoretically to alleviate the challenge in building supermassive black holes already at redshift $z \sim 7$, as numerous observations to date have confirmed.[1][8][9][10][11]



Artist's impression for the formation of a massive black hole seed via the direct black hole channel.[1]

Contents

Formation

Direct collapse black holes (DCBHs) are massive black hole seeds theorized to have formed in the high-redshift Universe and with typical masses at formation of ~$10^5\ M_\odot$, but spanning between $10^4\ M_\odot$ and $10^6\ M_\odot$. The environmental physical conditions to form a DCBH (as opposed to a cluster of stars) are the following:[3][4]

1. Metal-free gas (gas containing only hydrogen and helium).
2. Atomic-cooling gas.
3. Sufficiently large flux of Lyman-Werner photons, in order to destroy hydrogen r
efficient gas coolants.[12][13]

The previous conditions are necessary to avoid gas cooling and, hence, fragment
cloud. Unable to fragment and form stars, the gas cloud undergoes to a gravitat
structure, reaching extremely large values of the matter density at the core, of the
At this density, the object undergoes to a general relativistic instability,[14] which
black hole of a typical mass ~$10^5\ M_\odot$, and up to 1 million solar masses. The
relativistic instability, as well as the absence of the intermediate stellar phase, l
direct collapse black hole. In other words, these objects collapse directly from th
from a stellar progenitor as prescribed in standard black hole models.[15]

Demography

Montero, Pedro J.; Janka, Hans-Thomas; Müller, Ewald (2012-04-01). "Relativistic Collapse and Explosion of Rotating Supermassive Stars with Thermonuclear Effects" (http://adsabs.harvard.edu/abs/2012ApJ...749...37M). *The Astrophysical Journal*. **749** (1): 37. arXiv:1108.3090 (https://arxiv.org/abs/1108.3090). Bibcode:2012ApJ...749...37M (https://ui.adsabs.harvard.edu/abs/2012ApJ...749...37

Direct collapse black holes are generally thought to be extremely rare objects in because the three fundamental conditions for their formation (see above i challenging to be met all together in the same gas cloud.[16][17] Current cosmologic DCBHs could be as rare as only ~1 per cubic Giga-parsec at redshift 15.[17] The p density is highly dependent on the minimum flux of Lyman-Werner photons requ and can be as large as $\sim 10^7$ DCBHs per cubic Giga-parsec in the most optimistic s

M). doi:10.1088/0004-637X/749/1/37 (https://doi.org/10.1088%2F0004-637X%2F749%2F1%2F37). S2CID 119098587 (https://api.semanticscholar.org/CorpusID:119098587).

Detection

In 2016, a team led by Harvard University astrophysicist Fabio Pacucci identified the first two candidate direct collapse black holes,[19][20] using data from the Hubble Space Telescope and the Chandra X-ray Observatory.[21][22][23][24] The two candidates, both at redshift $z > 6$, were found in the CANDELS GOODS-S field and matched the spectral properties predicted for this type of astrophysical sources.[25] In particular, these sources are predicted to have a significant excess of infrared radiation, when compared to other categories of sources at high redshift.[19] Additional observations, in particular with the upcoming James Webb Space Telescope, will be crucial to investigate the properties of these sources and confirm their nature.[26]

References

1. "Chandra Press Room :: NASA Telescopes Find Clues For How Giant Black Holes Formed So Quickly :: 24 May 16" (https://chandra.si.edu/press/16_releases/press_052416.html). *chandra.si.edu*. Retrieved 2020-08-27.
2. Loeb, Abraham; Rasio, Frederic A. (1994-09-01). "Collapse of primordial gas clouds and the formation of quasar black holes" (http://adsabs.harvard.edu/abs/1994ApJ...432...52L). *The Astrophysical Journal*. **432**: 52–61. arXiv:astro-ph/9401026 (https://arxiv.org/abs/astro-ph/9401026). Bibcode:1994ApJ...432...52L (https://ui.adsabs.harvard.edu/abs/1994ApJ...432...52L). doi:10.1086/174548 (https://doi.org/10.1086%2F174548). S2CID 17042784 (https://api.semanticscholar.org/CorpusID:17042784).
3. Bromm, Volker; Loeb, Abraham (2003-10-01). "Formation of the First Supermassive Black Holes" (http://adsabs.harvard.edu/abs/2003ApJ...596...34B). *The Astrophysical Journal*. **596** (1): 34–46. arXiv:astro-ph/0212400 (https://arxiv.org/abs/astro-ph/0212400). Bibcode:2003ApJ...596...34B (https://ui.adsabs.harvard.edu/abs/2003ApJ...596...34B). doi:10.1086/377529 (https://doi.org/10.1086%2F377529). S2CID 14419385 (https://api.semanticscholar.org/CorpusID:14419385).
4. Lodato, Giuseppe; Natarajan, Priyamvada (2006-10-01). "Supermassive black hole formation during the assembly of pre-galactic discs" (http://adsabs.harvard.edu/abs/2006MNRAS.371.1813L). *Monthly Notices of the Royal Astronomical Society*. **371** (4): 1813–1823. arXiv:astro-ph/0606159 (https://arxiv.org/abs/astro-ph/0606159). Bibcode:2006MNRAS.371.1813L (https://ui.adsabs.harvard.edu/abs/2006MNRAS.371.1813L). doi:10.1111/j.1365-2966.2006.10801.x (https://doi.org/10.1111%2Fj.1365-2966.2006.10801.x). S2CID 13448595 (https://api.semanticscholar.org/CorpusID:13448595).
5. Siegel, Ethan. " 'Direct Collapse' Black Holes May Explain Our Universe's Mysterious Quasars" (https://www.forbes.com/sites/startswithabang/2017/12/26/direct-collapse-black-holes-may-explain-our-universes-mysterious-quasars/). *Forbes*. Retrieved 2020-08-27.
6. Yue, Bin; Ferrara, Andrea; Salvaterra, Ruben; Xu, Yidong; Chen, Xuelei (2014-05-01). "The brief era of direct collapse black hole formation" (http://adsabs.harvard.edu/abs/2014MNRAS.440.1263Y). *Monthly Notices of the Royal Astronomical Society*. **440** (2): 1263–1273. arXiv:1402.5675 (https://arxiv.org/abs/1402.5675). Bibcode:2014MNRAS.440.1263Y (https://ui.adsabs.harvard.edu/abs/2014MNRAS.440.1263Y). doi:10.1093/mnras/stu351 (https://doi.org/10.1093%2Fmnras%2Fstu351). S2CID 119275449 (https://api.semanticscholar.org/CorpusID:119275449).

7. Rees, Martin J.; Volonteri, Marta (2007-04-01). "Massive black holes: formation and evolution" (http://adsabs.harvard.edu/abs/2007IAUS..238...51R). *Black Holes from Stars to Galaxies -- Across the Range of Masses*. **238**: 51–58. arXiv:astro-ph/0701512 (https://arxiv.org/abs/astro-ph/0701512). Bibcode:2007IAUS..238...51R (https://ui.adsabs.harvard.edu/abs/2007IAUS..238...51R). doi:10.1017/S1743921307004681 (https://doi.org/10.1017%2FS1743921307004681). S2CID 14844338 (https://api.semanticscholar.org/CorpusID:14844338).
8. Bañados, Eduardo; Venemans, Bram P.; Mazzucchelli, Chiara; Farina, Emanuele P.; Walter, Fabian; Wang, Feige; Decarli, Roberto; Stern, Daniel; Fan, Xiaohui; Davies, Frederick B.; Hennawi, Joseph F. (2018-01-01). "An 800-million-solar-mass black hole in a significantly neutral Universe at a redshift of 7.5" (http://adsabs.harvard.edu/abs/2018Natur.553..473B). *Nature*. **553** (7689): 473–476. arXiv:1712.01860 (https://arxiv.org/abs/1712.01860). Bibcode:2018Natur.553..473B (https://ui.adsabs.harvard.edu/abs/2018Natur.553..473B). doi:10.1038/nature25180 (https://doi.org/10.1038%2Fnature25180). PMID 29211709 (https://pubmed.ncbi.nlm.nih.gov/29211709). S2CID 205263326 (https://api.semanticscholar.org/CorpusID:205263326).
9. Fan, Xiaohui; Narayanan, Vijay K.; Lupton, Robert H.; Strauss, Michael A.; Knapp, Gillian R.; Becker, Robert H.; White, Richard L.; Pentericci, Laura; Leggett, S. K.; Haiman, Zoltán; Gunn, James E. (2001-12-01). "A Survey of z>5.8 Quasars in the Sloan Digital Sky Survey. I. Discovery of Three New Quasars and the Spatial Density of Luminous Quasars at z~6" (http://adsabs.harvard.edu/abs/2001AJ....122.2833F). *The Astronomical Journal*. **122** (6): 2833–2849. arXiv:astro-ph/0108063 (https://arxiv.org/abs/astro-ph/0108063). Bibcode:2001AJ....122.2833F (https://ui.adsabs.harvard.edu/abs/2001AJ....122.2833F). doi:10.1086/324111 (https://doi.org/10.1086%2F324111). S2CID 119339804 (https://api.semanticscholar.org/CorpusID:119339804).
10. Yang, Jinyi; Wang, Feige; Fan, Xiaohui; Hennawi, Joseph F.; Davies, Frederick B.; Yue, Minghao; Banados, Eduardo; Wu, Xue-Bing; Venemans, Bram; Barth, Aaron J.; Bian, Fuyan (2020-07-01). "Poniua'ena: A Luminous z = 7.5 Quasar Hosting a 1.5 Billion Solar Mass Black Hole" (http://adsabs.harvard.edu/abs/2020ApJ...897L..14Y). *The Astrophysical Journal Letters*. **897** (1): L14. arXiv:2006.13452 (https://arxiv.org/abs/2006.13452). Bibcode:2020ApJ...897L..14Y (https://ui.adsabs.harvard.edu/abs/2020ApJ...897L..14Y). doi:10.3847/2041-8213/ab9c26 (https://doi.org/10.3847%2F2041-8213%2Fab9c26). S2CID 220042206 (https://api.semanticscholar.org/CorpusID:220042206).
11. "Monster Black Hole Found in the Early Universe" (https://www.gemini.edu/pr/monster-black-hole-found-early-universe). *Gemini Observatory*. 2020-06-24. Retrieved 2020-09-06.
12. Regan, John A.; Johansson, Peter H.; Wise, John H. (2014-11-01). "The Direct Collapse of a Massive Black Hole Seed under the Influence of an Anisotropic Lyman-Werner Source" (http://adsabs.harvard.edu/abs/2014ApJ...795..137R). *The Astrophysical Journal*. **795** (2): 137. arXiv:1407.4472 (https://arxiv.org/abs/1407.4472). Bibcode:2014ApJ...795..137R (https://ui.adsabs.harvard.edu/abs/2014ApJ...795..137R). doi:10.1088/0004-637X/795/2/137 (https://doi.org/10.1088%2F0004-637X%2F795%2F2%2F137). S2CID 119119172 (https://api.semanticscholar.org/CorpusID:119119172).
13. Sugimura, Kazuyuki; Omukai, Kazuyuki; Inoue, Akio K. (2014-11-01). "The critical radiation intensity for direct collapse black hole formation: dependence on the radiation spectral shape" (http://adsabs.harvard.edu/abs/2014MNRAS.445..544S). *Monthly Notices of the Royal Astronomical Society*. **445** (1): 544–553. arXiv:1407.4039 (https://arxiv.org/abs/1407.4039). Bibcode:2014MNRAS.445..544S (https://ui.adsabs.harvard.edu/abs/2014MNRAS.445..544S). doi:10.1093/mnras/stu1778 (https://doi.org/10.1093%2Fmnras%2Fstu1778). S2CID 119257740 (https://api.semanticscholar.org/CorpusID:119257740).
14. Montero, Pedro J.; Janka, Hans-Thomas; Müller, Ewald (2012-04-01). "Relativistic Collapse and Explosion of Rotating Supermassive Stars with Thermonuclear Effects" (http://adsabs.harvard.edu/abs/2012ApJ...749...37M). *The Astrophysical Journal*. **749** (1): 37. arXiv:1108.3090 (https://arxiv.org/abs/1108.3090). Bibcode:2012ApJ...749...37M (https://ui.adsabs.harvard.edu/abs/2012ApJ...749...37M). doi:10.1088/0004-637X/749/1/37 (https://doi.org/10.1088%2F0004-637X%2F749%2F1%2F37). S2CID 119098587 (https://api.semanticscholar.org/CorpusID:119098587).
15. Natarajan, Priyamvada. "The Puzzle of the First Black Holes" (https://www.scientificamerican.com/article/the-puzzle-of-the-first-black-holes/). *Scientific American*.

16. Agarwal, Bhaskar; Dalla Vecchia, Claudio; Johnson, Jarrett L.; Khochfar, Sadegh; Paardekooper, Jan-Pieter (2014-09-01). "The First Billion Years project: birthplaces of direct collapse black holes" (http://adsabs.harvard.edu/abs/2014MNRAS.443..648A). *Monthly Notices of the Royal Astronomical Society*. **443** (1): 648–657. arXiv:1403.5267 (https://arxiv.org/abs/1403.5267). Bibcode:2014MNRAS.443..648A (https://ui.adsabs.harvard.edu/abs/2014MNRAS.443..648A). doi:10.1093/mnras/stu1112 (https://doi.org/10.1093%2Fmnras%2Fstu1112). S2CID 119278181 (https://api.semanticscholar.org/CorpusID:119278181).
17. Habouzit, Mélanie; Volonteri, Marta; Latif, Muhammad; Dubois, Yohan; Peirani, Sébastien (2016-11-01). "On the number density of 'direct collapse' black hole seeds" (http://adsabs.harvard.edu/abs/2016MNRAS.463..529H). *Monthly Notices of the Royal Astronomical Society*. **463** (1): 529–540. arXiv:1601.00557 (https://arxiv.org/abs/1601.00557). Bibcode:2016MNRAS.463..529H (https://ui.adsabs.harvard.edu/abs/2016MNRAS.463..529H). doi:10.1093/mnras/stw1924 (https://doi.org/10.1093%2Fmnras%2Fstw1924). S2CID 118409029 (https://api.semanticscholar.org/CorpusID:118409029).
18. Latif, M. A.; Bovino, S.; Grassi, T.; Schleicher, D. R. G.; Spaans, M. (2015-01-01). "How realistic UV spectra and X-rays suppress the abundance of direct collapse black holes" (http://adsabs.harvard.edu/abs/2015MNRAS.446.3163L). *Monthly Notices of the Royal Astronomical Society*. **446** (3): 3163–3177. arXiv:1408.3061 (https://arxiv.org/abs/1408.3061). Bibcode:2015MNRAS.446.3163L (https://ui.adsabs.harvard.edu/abs/2015MNRAS.446.3163L). doi:10.1093/mnras/stu2244 (https://doi.org/10.1093%2Fmnras%2Fstu2244). S2CID 119219917 (https://api.semanticscholar.org/CorpusID:119219917).
19. Pacucci, Fabio; Ferrara, Andrea; Grazian, Andrea; Fiore, Fabrizio; Giallongo, Emanuele; Puccetti, Simonetta (2016-06-01). "First identification of direct collapse black hole candidates in the early Universe in CANDELS/GOODS-S" (http://adsabs.harvard.edu/abs/2016MNRAS.459.1432P). *Monthly Notices of the Royal Astronomical Society*. **459** (2): 1432–1439. arXiv:1603.08522 (https://arxiv.org/abs/1603.08522). Bibcode:2016MNRAS.459.1432P (https://ui.adsabs.harvard.edu/abs/2016MNRAS.459.1432P). doi:10.1093/mnras/stw725 (https://doi.org/10.1093%2Fmnras%2Fstw725). S2CID 118578313 (https://api.semanticscholar.org/CorpusID:118578313).
20. "The first Direct Collapse Black Hole candidates" (https://www.fabiopacucci.com/impact/press-coverage/the-first-direct-collapse-black-hole-candidates/). *Fabio Pacucci*. Retrieved 2020-09-29.
21. Northon, Karen (2016-05-24). "NASA Telescopes Find Clues For How Giant Black Holes Formed So Quickly" (http://www.nasa.gov/press-release/nasa-telescopes-find-clues-for-how-giant-black-holes-formed-so-quickly). *NASA*. Retrieved 2020-09-28.
22. "Mystery of supermassive black holes might be solved" (https://www.cbsnews.com/news/mystery-of-supermassive-black-holes-might-be-solved/). *www.cbsnews.com*. Retrieved 2020-09-28.
23. "Mystery of Massive Black Holes May Be Answered by NASA Telescopes" (https://abcnews.go.com/Technology/mystery-massive-black-holes-answered-nasa-telescopes/story?id=39364430). *ABC News*. Retrieved 2020-09-28.
24. Reynolds, Emily (2016-05-25). "Hubble discovers clues to how supermassive black holes form" (https://www.wired.co.uk/article/hubble-space-telescope-black-holes). *Wired UK*. ISSN 1357-0978 (https://www.worldcat.org/issn/1357-0978). Retrieved 2020-09-28.
25. Pacucci, Fabio; Ferrara, Andrea; Volonteri, Marta; Dubus, Guillaume (2015-12-01). "Shining in the dark: the spectral evolution of the first black holes" (http://adsabs.harvard.edu/abs/2015MNRAS.454.3771P). *Monthly Notices of the Royal Astronomical Society*. **454** (4): 3771–3777. arXiv:1506.05299 (https://arxiv.org/abs/1506.05299). Bibcode:2015MNRAS.454.3771P (https://ui.adsabs.harvard.edu/abs/2015MNRAS.454.3771P). doi:10.1093/mnras/stv2196 (https://doi.org/10.1093%2Fmnras%2Fstv2196). S2CID 119187129 (https://api.semanticscholar.org/CorpusID:119187129).
26. Natarajan, Priyamvada; Pacucci, Fabio; Ferrara, Andrea; Agarwal, Bhaskar; Ricarte, Angelo; Zackrisson, Erik; Cappelluti, Nico (2017-04-01). "Unveiling the First Black Holes With JWST:Multi-wavelength Spectral Predictions" (http://adsabs.harvard.edu/abs/2017ApJ...838..117N). *The Astrophysical Journal*. **838** (2): 117. arXiv:1610.05312 (https://arxiv.org/abs/1610.05312). Bibcode:2017ApJ...838..117N (https://ui.adsabs.harvard.edu/abs/2017ApJ...838..117N). doi:10.3847/1538-4357/aa6330 (https://doi.org/10.3847%2F1538-4357%2Faa6330). S2CID 88502812 (https://api.semanticscholar.org/CorpusID:88502812).