Among the most fascinating objects that astronomers today can study are the bizarre, collapsed corpses of massive stars that have come to be called black holes. Around these incredibly dense star-remnants, gravity becomes so strong that nothing, not even light, can escape. In the last few decades, new instruments in space have enabled astronomers to detect the presence of black holes for the first time. Being black and very small, these objects are hard to “see” directly, but we can sometimes find them by watching them “eat”. Smaller black holes are found when they are caught having their companion stars for lunch. At the centers of large galaxies, much larger black holes are often seen consuming their “neighborhood”, pulling in large quantities of gas, dust, and larger bodies. In the process, excess “food” is being spit out into vast jets extending in opposite directions, which can signal the presence of the central black hole to great distances. Many general books and articles on astronomy include brief coverage of black holes these days. The list below is a selection of non-technical resources that you may find useful if you want to begin exploring the world of black holes in more detail.

1. Selected Introductory Books on Black Holes

Al-Khalili, Jim Black Holes, Wormholes, and Time Machines. 1999, Institute of Physics Publishing. A British physicist gives a grand overview of some of the most far-out aspects of black-hole science.


Kaufmann, William Cosmic Frontiers of General Relativity. 1977, Little Brown. For those who want more non-technical details about the different types of black holes; out of print, but well worth searching out.


Thorne, Kip Black Holes and Time Warps. 1994, W. W. Norton. The long, definitive introduction by one of the leading scientists in the field; a bit technical in places.


2. A Few Introductory Readings on the General Theory of Relativity

Wheeler, John A Journey Into Gravity and Spacetime. 1990, Scientific American Library. A brilliant, demanding introduction by one of the foremost scientists of our time (the man who helped coin the word “black hole”.)

Will, C. Was Einstein Right? — Putting General Relativity to the Test. 1986, Basic Books. Introduction to the experiments that confirm the theory.

Zee, A. An Old Man’s Toy: Gravity in Einstein’s Universe. 1989, Macmillan. Good, non-technical primer by a physicist.


double pulsar.

3. Selected Nontechnical Articles on Stellar-mass Black Holes


Nadis, S. “What Happens When Black Holes Collide” in Astronomy, May 2006, p. 34. Theoretical ideas on ways black hole mergers may lead to their ejection from a galaxy. (Far out)


4. Articles on the Super-massive Black Hole at the Center of the Milky Way Galaxy

Dvorak, J. “Journey to the Heart of the Milky Way” in Astronomy, Feb. 2008, p. 28. Measuring nearby stars to determine the properties of the black hole at the center.


Tanner, A: “A Trip to the Galactic Center” in Sky & Telescope, Apr. 2003, p. 44. Nice introduction with observations pointing to the presence of a black hole. (see also: http://www.astro.ucla.edu/~ghezgroup/gc/journey/)

5. Articles on Super-massive Black Holes in General


Irion, Robert “A Quasar in Every Galaxy?” in Sky & Telescope, July 2006, p. 40. Discusses how supermassive black holes powering the centers of galaxies may be more common than thought.


Nadis, Steve “Here, There, and Everywhere” in *Astronomy*, Feb. 2001, p. 34. On Hubble observations showing how common supermassive black holes are in galaxies.


Voit, G. “The Rise and Fall of Quasars” in *Sky & Telescope*, May 1999, p. 40. Explains the behavior of quasars in terms of the supermassive black holes that are thought to be the power source.

Wanjek, Christopher “How Black Holes Helped Build the Universe” in *Sky & Telescope*, Jan. 2007, p. 42. On the energy and outflow from disks around supermassive black holes; nice introduction.


6. A Few Readings on the Life and Work of Stephen Hawking


Some parts of this best-seller are a bit more difficult than its sales might make you believe. (The book now exists in several versions — some annotated — and has spin-off readers’ guides, videos, etc.)

Also see his *Black Holes and Baby Universes* (1993, Bantam) for further thoughts and elaborations.


7. A Few Web Sites with Black Hole Information or Animations


Frequently Asked Questions about Black Holes (written by University of Richmond physicists Ted Bunn in 1995, while he was a graduate student at Berkeley; a bit dated, but still good): http://cosmology.berkeley.edu/Education/BHfaq.html

The Universe in the Classroom (The ASP’s Newsletter on Teaching Astronomy) Issue on Black Holes by John Percy: http://www.astrosoce.org/education/publications/tntl/24/24.html


*StarDate’s* Introduction to Black Holes: http://blackholes.stardate.org/

87 Questions and Answers about Black Holes from astronomer Sten Odenwald’s *Astronomy Café*: http://www.astronomycafe.net/qadir/abholes.html
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Monsters in Galactic Nuclei (an article on supermassive black holes by John Kormendy and Gregory Shields from StarDate Magazine): http://chandra.as.utexas.edu/~kormendy/stardate.html

Monster of the Milky Way (companion site to the PBS-TV NOVA episode on the black hole at the center of our Galaxy): http://www.pbs.org/wgbh/nova/blackhole/

Black Hole Math (a nice introductory booklet at the high-school math level by astronomer Sten Odenwald): http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Black_Hole_Math.html

Spacetime Wrinkles Website: http://archive.ncsa.illinois.edu/Cyberia/NumRel/NumRelHome.html The National Center for Supercomputing Applications Relativity Group (whew — what a name!) has set up an intriguing and well produced “exhibit on line” about Einstein’s theory of relativity and its astronomical implications, including some movies in which they simulate situations such as the collision of two black holes.

The Light Cone: http://physics.syr.edu/courses/modules/LIGHTCONE/ Rob Salgado of Syracuse University has produced a series of simulations that explain ideas in special and general relativity theory and provide a glossary and links.

Black Hole Animations: Using high-speed computers, several groups of physicists have simulated the behavior of black holes and what it might be like to fall into one. Among the sites with web-movies from such simulations are:

- Falling Into a Black Hole (animations by Andrew Hamilton): http://casa.colorado.edu/~ajsh/schw.shtml

8. Black Holes for Educators

For a set of black hole information guides and demonstration activities from the ASP's and JPL's Night Sky Network, click on: http://nightsky.jpl.nasa.gov/download-search.cfm and check the box on black holes.

The Universe in the Classroom (The ASP's Newsletter on Teaching Astronomy) Issue on Black Holes by John Percy: http://www.astrosociety.org/education/publications/tnl/24/24.html


Black Hole Math (a nice introductory booklet at the high-school math level by astronomer Sten Odenwald): http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Black_Hole_Math.html


9. Some Science Fiction Stories with Good Science about Black Holes


Baxter, Stephen “Pilot” in Vacuum Diagrams. 1997, Harper Prism. An asteroid space ship being chased by an enemy missile goes through the ergosphere of a rotating black hole, taking energy out and making the chasing missile fall in the event horizon.

Benford, Gregory Eater. 2000, Eos/HarperCollins. An ancient intelligent black hole comes to our solar system.

Brin, David “The Crystal Spheres” in The River of Time. 1987, Bantam. Advanced races use black holes to bear with the loneliness of a universe in which life is still rare.

Brin, David Earth. 1990, Bantam. A mini black hole falls into the Earth's core.

Haldeman, Joe The Forever War. 1974, Ballantine. An interstellar war is fought using black holes for travel between battles.

Johnson, Bill “Meet Me at Apogee” in Carr, T., ed. The Best Science Fiction of the Year 12. 1983, Pocket Books. Posits a future in which people (with alien
help) organize levels of descent near a black hole; so the two-month level is where one day of experienced time for travelers equals two months in the outside universe. Prospectors and people with incurable disease hire pilots to take them down to lower levels.

Landis, Geoffrey “Impact Parameter” in Impact Parameter. 2001, Golden Gryphon. A newly discovered gravitational lens turns out to be a wormhole being used by an alien civilization to visit us.

Landis, Geoffrey “Approaching Perimelasma” in Impact Parameter. 2001, Golden Gryphon. In the far future, a virtual human is dropped into a black hole and makes an interesting discovery about space and time.

McAuley, Paul “How We Lost the Moon” in Crowther, Peter, ed. Moon Shots. 1999, Daw. A glitch in a fusion experiment on the Moon creates a mini black hole that eats our satellite.

McDevitt, Jack & Shara, Michael “Lighthouse” in Cryptic: The Best Short Fiction of Jack McDevitt. (2009, Subterranean Press) [also on the web at: http://www.webscription.net/chapters/1596061958/1596061958___8.htm] An alien race decides, as a public service, to mark the location of unaccompanied black holes in the Galaxy by putting very strange brown dwarfs around them that could not exist in nature. Shara is an astronomer.

Niven, Larry World Out of Time. 1976, Ballantine. Protagonist uses a supermassive black hole to travel into distant future.


Pohl, Fred Gateway. 1977, Ballantine. Enjoyable novel with rotating black holes, event horizons, and “black hole guilt”. (Has a series of sequels where the science gets too “far out” for inclusion on this list.)

Sagan, Carl Contact. 1985, Simon & Schuster. The protagonists use a kind of black hole-wormhole “subway” system for interstellar travel, designed by astrophysicist Kip Thorne and his students.

Sheffield, Charles “Killing Vector” in Vectors. 1979, Ace. Mini-black holes are used for space propulsion. Sheffield has a PhD in physics.

Varley, John The Ophiuchi Hotline. 1977, Dell. Complex novel, in which mini black holes are hunted as energy sources.


Wheeler, J. Craig The Krone Experiment. 1986, Pressworks. Mini black holes pose a threat to the Earth; written by an astronomer.

Willis, Connie “Schwarzschild Radius” in Preiss, Byron & Fraknoi, Andrew, eds. The Universe. 1987, Bantam. Haunting story combining episodes from the life of Karl Schwarzschild and black hole images.

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