13.22: Active Galaxies, Quasars, and Supermassive Black Holes (Exercises)

For Further Exploration

Articles

Bartusiak, M. “A Beast in the Core.” *Astronomy* (July 1998): 42. On supermassive black holes at the centers of galaxies.

Disney, M. “A New Look at Quasars.” *Scientific American* (June 1998): 52.

Djorgovski, S. “Fires at Cosmic Dawn.” *Astronomy* (September 1995): 36. On quasars and what we can learn from them.

Ford, H., & Tsvetanov, Z. “Massive Black Holes at the Hearts of Galaxies.” *Sky & Telescope* (June 1996): 28. Nice overview.

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

Kormendy, J. “Why Are There so Many Black Holes?” *Astronomy* (August 2016): 26. Discussion of why supermassive black holes are so common in the universe.

Kruesi, L. “Secrets of the Brightest Objects in the Universe.” *Astronomy* (July 2013): 24. Review of our current understanding of quasars and how they help us learn about black holes.

Miller, M., et al. “Supermassive Black Holes: Shaping their Surroundings.” *Sky & Telescope* (April 2005): 42. Jets from black hole disks.

Nadis, S. “Exploring the Galaxy–Black Hole Connection.” *Astronomy* (May 2010): 28. Overview.

Nadis, S. “Here, There, and Everywhere.” *Astronomy* (February 2001): 34. On Hubble observations showing how common supermassive black holes are in galaxies.

Nadis, S. “Peering inside a Monster Galaxy.” *Astronomy* (May 2014): 24. What X-ray observations tell us about the mechanism that powers the active galaxy M87.

Olson, S. “Black Hole Hunters.” *Astronomy* (May 1999): 48. Profiles four astronomers who search for “hungry” black holes at the centers of active galaxies.

Peterson, B. “Solving the Quasar Puzzle.” *Sky & Telescope* (September 2013): 24. A review article on how we figured out that black holes were the power source for quasars, and how we view them today.

Tucker, W., et al. “Black Hole Blowback.” *Scientific American* (March 2007): 42. How supermassive black holes create giant bubbles in the intergalactic medium.

Voit, G. “The Rise and Fall of Quasars.” *Sky & Telescope* (May 1999): 40. Good overview of how quasars fit into cosmic history.

Wanjek, C. “How Black Holes Helped Build the Universe.” *Sky & Telescope* (January 2007): 42. On the energy and outflow from disks around supermassive black holes; nice introduction.

Websites

Monsters in Galactic Nuclei: http://chandra.as.utexas.edu/stardate.html. An article on supermassive black holes by John Kormendy, from *StarDate* magazine.

Quasar Astronomy Forty Years On: http://www.astr.ua.edu/keel/agn/quasar40.html. A 2003 popular article by William Keel.

Quasars and Active Galactic Nuclei: www.astr.ua.edu/keel/agn/. An annotated gallery of images showing the wide range of activity in galaxies. There is also an introduction, a glossary, and background information. Also by William Keel.

Videos

Black Hole Chaos: The Environments of the Most Supermassive Black Holes in the Universe: https://www.youtube.com/watch?v=hzSgU-3d8QY. May 2013 lecture by Dr. Belinda Wilkes and Dr. Francesca Civano of the Center for Astrophysics in the CfA Observatory Nights Lecture Series (50:14).

Hubble and Black Holes: http://www.spacetelescope.org/videos/hubblecast43a/. Hubblecast on black holes and active galactic nuclei (9:10).

Monster Black Holes: https://www.youtube.com/watch?v=LN9oYjNKBm8. May 2013 lecture by Professor Chung-Pei Ma of the University of California, Berkeley; part of the Silicon Valley Astronomy Lecture Series (1:18:03).

Review Questions

1. Describe some differences between quasars and normal galaxies.
2. Describe the arguments supporting the idea that quasars are at the distances indicated by their redshifts.
3. In what ways are active galaxies like quasars but different from normal galaxies?
4. Why could the concentration of matter at the center of an active galaxy like M87 not be made of stars?
5. Describe the process by which the action of a black hole can explain the energy radiated by quasars.
6. Describe the observations that convinced astronomers that M87 is an active galaxy.
7. Why do astronomers believe that quasars represent an early stage in the evolution of galaxies?
8. Why were quasars and active galaxies not initially recognized as being “special” in some way?
9. What do we now understand to be the primary difference between normal galaxies and active galaxies?
10. What is the typical structure we observe in a quasar at radio frequencies?
11. What evidence do we have that the luminous central region of a quasar is small and compact?

Thought Questions

1. Suppose you observe a star-like object in the sky. How can you determine whether it is actually a star or a quasar?
2. Why don’t any of the methods for establishing distances to galaxies, described in Galaxies (other than Hubble’s law itself), work for quasars?
3. One of the early hypotheses to explain the high redshifts of quasars was that these objects had been ejected at very high speeds from other galaxies. This idea was rejected, because no quasars with large blueshifts have been found. Explain why we would expect to see quasars with both blueshifted and redshifted lines if they were ejected from nearby galaxies.
4. A friend of yours who has watched many *Star Trek* episodes and movies says, “I thought that black holes pulled everything into them. Why then do astronomers think that black holes can explain the great *outpouring* of energy from quasars?” How would you respond?
5. Could the Milky Way ever become an active galaxy? Is it likely to ever be as luminous as a quasar?
6. Why are quasars generally so much more luminous (why do they put out so much more energy) than active galaxies?
7. Suppose we detect a powerful radio source with a radio telescope. How could we determine whether or not this was a newly discovered quasar and not some nearby radio transmission?
8. A friend tries to convince you that she can easily see a quasar in her backyard telescope. Would you believe her claim?
