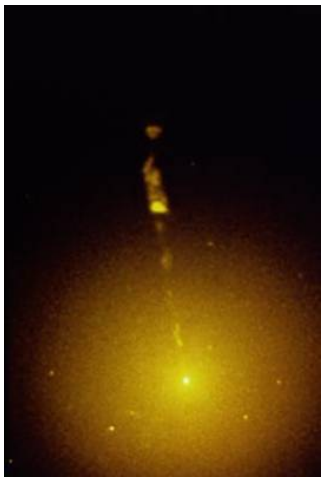
Every Galaxy has a massive black hole. Review—20 Nov

- Homework 9 is due at the end of class.
  - Pick up answers.
  - Answers will also be on angel.
- Black holes in the centers of galaxies
  - Wed: Milky Way has a black hole with 4×10^6 M_{sun}.
  - Black hole in M87
  - Every galaxy has one.
- Review for Test 3: Top 10 questions asked at office hours.

Measurement of Mass of Black Hole in M87

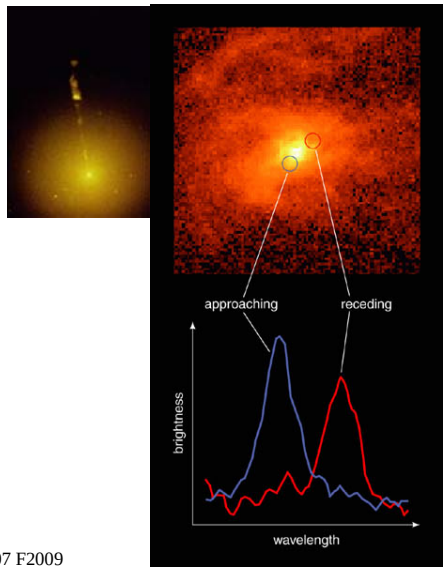
- The bright center may be a dense concentration of stars.

1. What must you measure to find the mass of the black hole in M87, a big elliptical galaxy?
   a. Luminosity of nucleus
   b. Distance to M87
   c. Size of orbit & speed of something in orbit
   d. Speed of ejected material



Measurement of Mass of Black Hole in M87

- To find the mass of black hole in M87, a big elliptical galaxy, use Kepler's 3rd Law.
  - Mass = $R^3/P^2 = RV^2$
  - R = 60ly
  - V = 800km/s
  - M = 3Billion$M_\odot$
  - (1000 times mass of the black hole in center of Milky Way.)
- If the mass were stars, density is 15,000 times that in sun's neighborhood.



Every galaxy has a massive black hole in the center

- There is a 3Billion $M_\odot$ black hole in the center of M87, and a 4Million $M_\odot$ black hole in the center of Milky Way.
- Karl Gebhardt (and others) found that the mass of the black hole is proportional to the mass of the galaxy. (Karl was an MSU graduate student; now a prof. at U Texas.)
  - $\Rightarrow$ Every galaxy has a massive black hole in the center.

- Summarizing questions

1. What is the evidence that CygX1 has a black hole?
2. What is the evidence for a massive black hole at the center of the Milky Way Galaxy?

Review for test 3: Top ten questions asked during office hours

- Test 3 is Mon.
  - Test 3 covers material not on test 2 through mass of galaxies (2nd half of 12 Oct through 1st half of 16 Nov).
  - Homework 6–9.
  - One 8.5×11 cheat sheet. You may write on the front and back.
  - We covered a lot of material. Material from earlier tests will not be on this one.
- Mass of galaxies
- Formation of helium in the Big Bang
- Radiation from the Big Bang
- Hubble's Law
- Death of stars
- Nuclear fusion

Hwk 8

- **Simplicio thinks**, "Penzias and Wilson probably detected the radiation from the evergreen trees nearby. Their radio antenna will receive signals even when not pointed directly at the trees, just as my satellite dish gets a signal even when not pointed directly at the satellite. The radiation is not from the Big Bang." What evidence refutes Simplicio's incorrect statement?

1. Common erroneous answer: The radiation *is* from the Big Bang. Why is this erroneous? This is a conclusion, not evidence.

- Key ideas
  - Trees emit thermal radiation.
  - Objects emit more thermal radiation when the temperature is higher.
  - PW found the radiation is "free from seasonal variation."
- The radiation is free of seasonal variations. If the radiation were from trees, it would be more intense in the summer when the trees are warmer.

Hwk 8

- **The Lives of the Helium Nuclei**. Write a short, short story about the life of a helium nucleus in the center of the sun. Helium can be made in several ways. Assume this helium nucleus was made in the most common way. Include (3 pts.) how it was born, (3 pts.) what it was before birth, and (3 pts.) what it may become when the sun dies.
- Key ideas addressed by this question
  - Most of the helium was made in the Big Bang.
  - In the BB, helium formed when the temperature cooled enough for deuterium to form.
  - What happens to the core of the sun?

Hwk 8

- The picture shows a sample of the universe 0.001 s after the big bang, when the expansion parameter was 6×10^{-12}. (Recall that the expansion parameter is distance/(present distance). The box was a cube 2×10^{-11}m on a side. There are 8 neutrons, 8 protons, and lots of light in the box.
  - (5 pts.) The box expands with the universe. Draw its contents just before helium formed (at 3 minutes, when the expansion parameter is 2.3×10^{-9}). The number must be precise to 10%; for example, drawing 15 protons is OK if the actual number of protons is 16.

1. Which BIG idea is needed?
   A. Temperature cools by same factor as U expands.
   B. Neutrons change into protons & vice versa.
   C. Helium forms from deuterium.
   D. Deuterium forms when the temperature is cool enough.
   E. Neutrons inside ^{4}He are stable.

Hwk 8

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  - The box expands with the universe. (3 pts.) Draw its contents at the present time. Assume the box is not from some special place such as in a star, or in a galaxy.

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Homework 7

- The present distance to Hoag's Object is 300 Mpc, and its speed is 18,000 km/s. For Hubble's constant, use the value 60 km/s/Mpc, which is equal to 0.061/Byr. A Mpc is 3.1×10^{19} km. A billion years is 3×10^{16} s.
  - (3 pts.) Three billion years ago, Hoag's Object was moving away from us at about the same speed. What is the reason for that?
  - What is the big idea?
  - How far from us was Hoag's Object at that time?
  - Equivalent question: I am in Grand Rapids 60 mi from EL. I am moving at 10mph. How far from EL was I an hour ago?

Homework 6

- The solar system including the sun is 4.6 billion year old. Consider a carbon nucleus that eventually became part of my hand. That nucleus existed before the sun formed.
  - (3 pts.) Describe a possible environment of that carbon nucleus 1 billion years ago.
  - (3 pts.) Describe a possible environment of that carbon nucleus 5 billion years ago.
- What big ideas?

Homework 6

- The Life of the Sun.
  - (2 pts.) Why is no lifetime given for the white dwarf stage?
  - (2 pts.) Why is the sun as a white dwarf so much smaller than it is now?
- What big ideas?