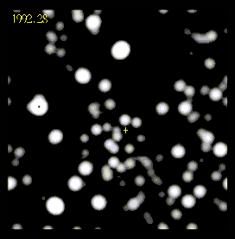
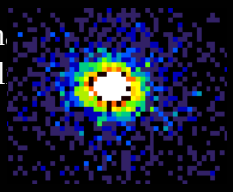
Black Holes & Quasars—18 Nov

- Black hole
  - Mass is so concentrated that nothing escapes
- Quasar
  - Black holes in the center of galaxies th is lit by material fall in toward the black hole.



BH in center of Milky Way



BH Cyg X1

Jet in galaxy M87

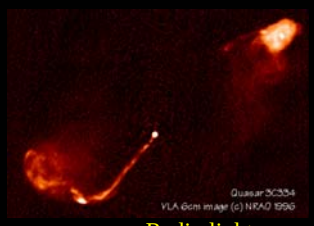
Black holes / Quasars —18 Nov

- Quasars are black holes lit by material falling into them.
- Black holes in center of Milky Way & M87
- Our Dusty Universe: Astronomical Horizons Lecture
  - "Come learn how microscopic particles of dust in the universe frustrate and enlighten astronomers in their quest to understand the cosmos."
  - Heather Jacobson
  - Thurs, 7:30 at Planetarium
- Hwk 9 is due Fri, 20th.
  - No late papers. Answers will be handed out and put on angel after class.
  - Missouri Club today.
- Observing today & Thurs, Nov 18 & 19, 6:30-10:00pm
  - Attend only if stars are visible. See angel after 5:00pm, if weather is ambiguous. Rain predicted.
  - Quiz. You will be asked to locate a star using the Abrams Planetarium star chart. Quiz counts as one extra-credit clicker assignment.
  - Go to the south end of the building (toward Wilson Rd.) & take the elevator up to the penthouse.
- Test 3 is on Mon, 23rd.
  - Covers material through "dark matter" (Mon, 16th and Hwk 9).
- No class on Wed, 25th.

Discovery of quasars (quasi-stellar objects)

- Some sources of radio waves are coincident with stars.
- Stars do not emit light at radio wavelengths.
- Are they some kind of weird star within the Milky Way Galaxy?


Visible light



Radio light

Discovery of quasars (quasi-stellar objects)

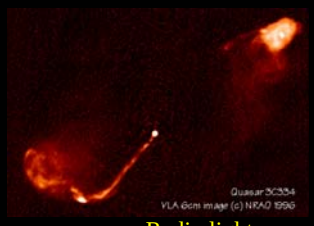
- Maarten Schmidt gets a spectrum.
  - "Star" was moving at 40,000 km/s. (Hwk 7)
  - Fastest stars in Milky Way move at 200km/s.

1. Why is it moving so fast?

A. It is in a distant galaxy.

B. It was shot out of the MW.

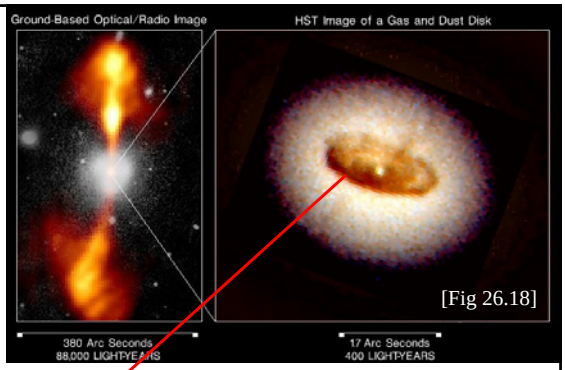

Visible light



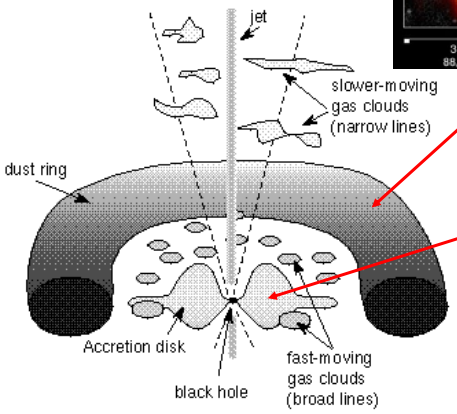
Radio light

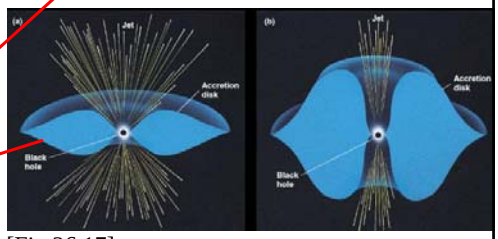
Energy Source:

• Gas, stars fall into 10^8 $M_\odot$ black hole.
• Gravitational potential energy ➔ thermal energy ➔ light



[Fig 26.18]





[Fig 26.17]

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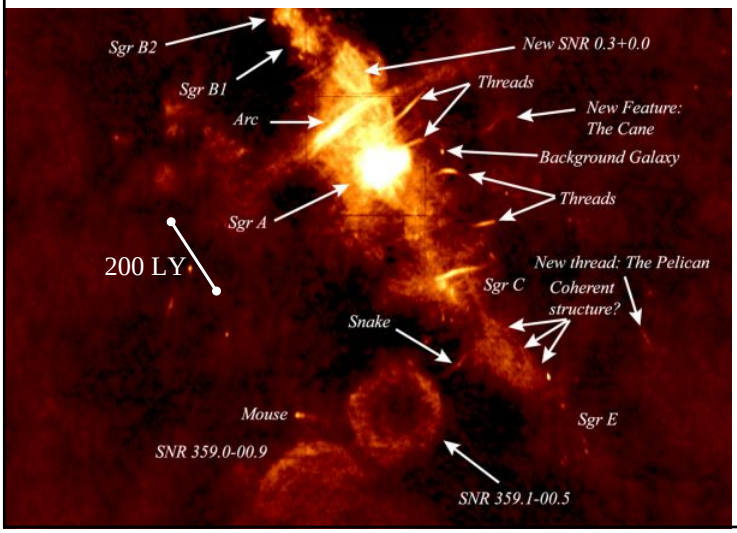
Accretion disk + Black Hole + Jets

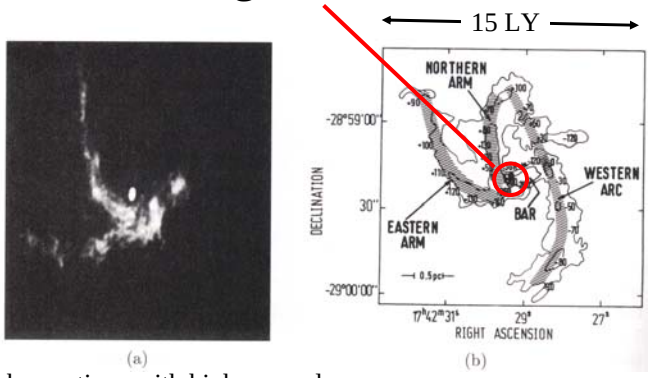
The Center of our Milky Way Galaxy

Visible light



Radio waves

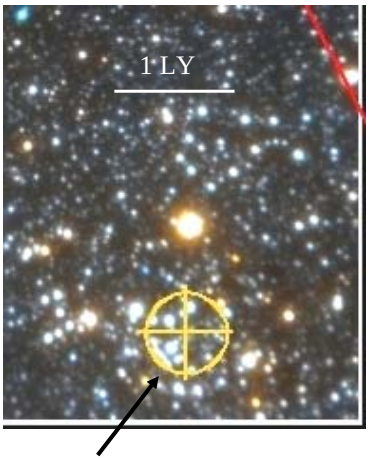
Sagittarius A*



Radio observations with higher angular resolution.

Small oval is the point source Sagittarius A*
= center of galaxy

Infrared Images of the Galactic Center



Using "adaptive optics" technique on Gemini 8m telescope.

Galactic Center (Sagittarius A*)

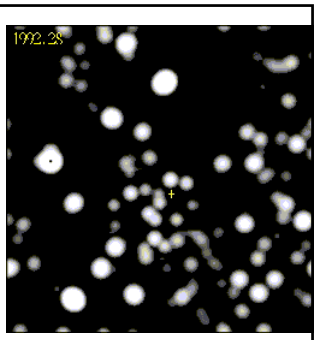
Density of stars is 300,000 x greater than in vicinity of Sun

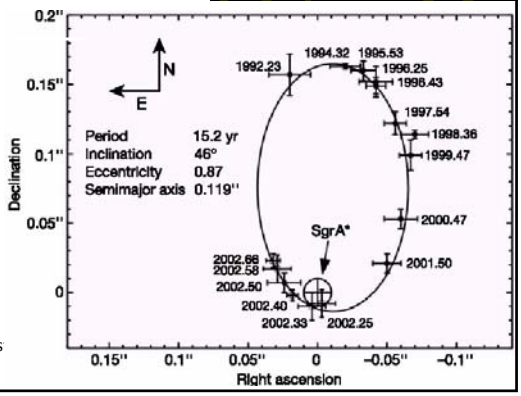
Black Hole at the Center of the Milky Way Galaxy

- From 2002.25 to 2002.40 (0.15yr), star moved same as it did from 1995.53 to 1996.43 (0.9yr).

1. Why did the star move so fast when it was near Sgr A*?
   a. Kepler's law of equal areas
   b. It got sucked in by the black hole.
   c. The black hole spit it out.
   d. There is mass near the black hole

Infrared observations over 6 years.



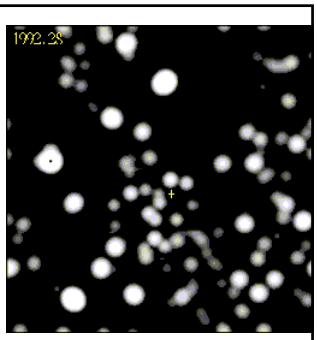


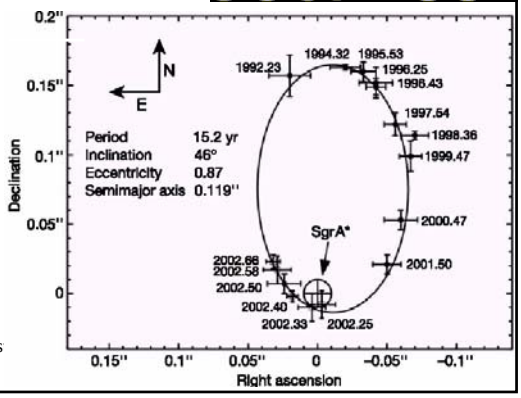
As

Black Hole at the Center of the Milky Way Galaxy

- Orbit is a ellipse tilted by 46°
- Data from 2002 goes within 60AU from black hole. [Orbit of Pluto is 40AU.]
- Within 60AU, the mass at SgrA* acts like a point.
- Orbit is consistent with Sag A being a black hole.

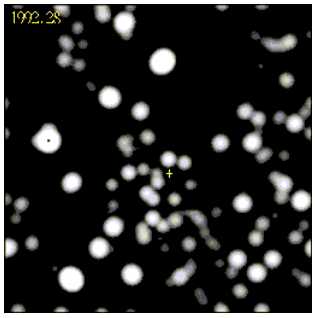
Infrared observations over 6 years.





As

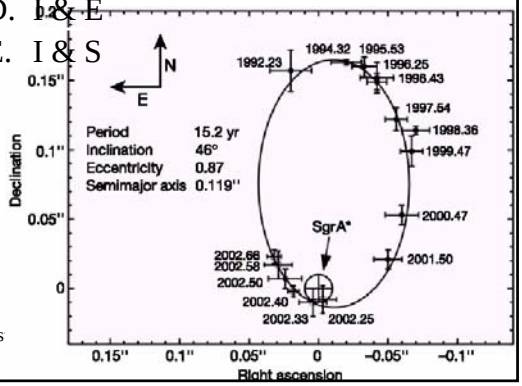
The Black Hole at the the Galactic Center



Infrared observations over 6 years.

Measure orbits of stars in very center.

1. To deduce the mass, what quantities do you need from the figure?
   A. Period & inclination
   B. P & eccentricity
   C. P & semi major axis
   D. I & E
   E. I & S



As

Mass of the black hole in the center of our galaxy

- A star orbits Sgr A in an elliptical orbit with a period of 14 yr. The semi major axis of the orbit is 1000 AU. Show how to find the mass of Sgr A. Give the numerical answer for the mass. (It is easiest to express the mass in solar mass, rather than in kg.)

1. What is the key big idea needed to figuring out the mass from the observations?
   A. Kepler's 3rd Law
   B. Orbit is an ellipse.
   C. Period is expressed in years.
   D. Semi major axis is expressed in AU.

- Use Newton's version of Kepler's Third Law: $P^2=R^3/M$, where the period P is in years, the semi major axis R is in AU, and the mass M in solar masses.

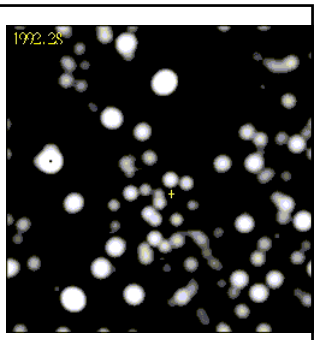
  $M = R^3/P^2 = 1000^3/14^2 = 5\times10^6\ M_{sun}$.

- The actual period is 15.2yr, and the actual semi major axis is 950AU.

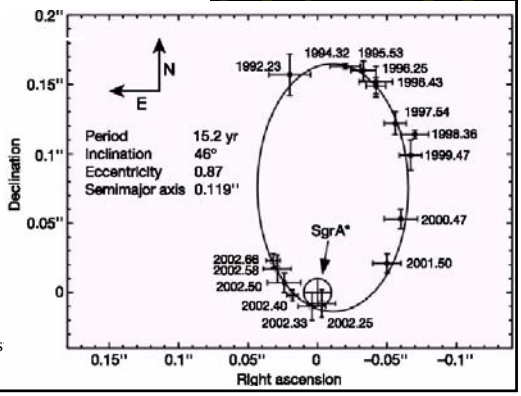
  $M= 952^3/15.2^2= 4\times10^6\ M_{sun}$.

Black Hole at the Center of the Milky Way Galaxy

- Orbit is a ellipse. Data from 2002 goes within 60AU from black hole. [Orbit of Pluto is 40AU.]
- Within 60AU, the mass at SgrA* acts like a point.
- Orbit is consistent with Sgr A* being a black hole.
- If SgrA* is made of stars, there would be a million stars packed within the size of the solar system. The stars would collide.
- Therefore Sgr A* is a black hole.



Infrared observations over 6 years.



As