Winners of the OBAFGKM Mnemonic

On **B**reak **A** **F**riendly **G**uy **K**issed **M**om?–Aarika Gerstler
Oscar Bought A Fried Guppy Kiddie Meal — Corinne Copeland
Obese Benny Asked For Glazed Kellogg's Maltomeal — Jonathan Vanderlee
Old Bakers Are Fairly Good Kneader-Men — Matthew Milia
Only Bad Astronomers Feel Good Knowing Mnemonics — Dash Dudley
Oh Be A Friend! Give Kevin Money — Andrew Mouranie
Oh Boy, An F Grade Kills Me. — David Moll
October Brings A Football Game; Kill Michigan — Emy Ibrahim
Only Bears Are Found Grazing Kalamazoo's Meijer — Stephanie Cady
Our Blessings Are From God's Kingdom Majestic — Latoya Baker
One Boy Ate Five Green Killer Mosquitoes — Kyle Bridges
Obese Badgers Attack Furiously, Gnawing/Killing Many — John Mallory
On Bob's Animal Farm, George Kept Mice — Whitney Jackson
Only Boring Astronomers Find Glee Knowing Mnemonics — Korina Raiford
Only Boys Accepting Feminism Get Kissed Meaningfully — David Silverman
Onion Breath Amidst Flaming Gingivitis Kills Molars —. James Falkowski

Quasars & Active Galactic Nuclei—4 April

Cygnus A

3C273

- Most big galaxies have a black hole in the nucleus.
- In quasars, the nucleus is so bright that that the galaxy looks like a point.
- Mass of the black hole
  $3,000,000,000 M_\odot$ in M87
  $3,000,000 M_\odot$ in Milky Way
- Material can be ejected along the spin axis.
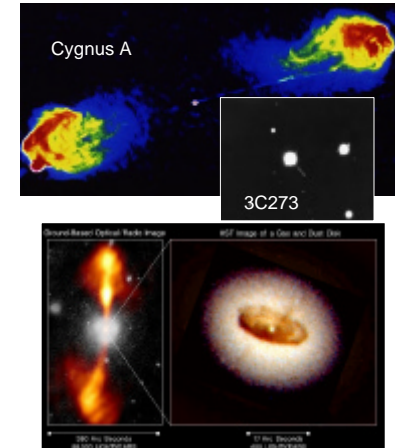
Quasars: Quasi-Stellar Radio Sources [26]
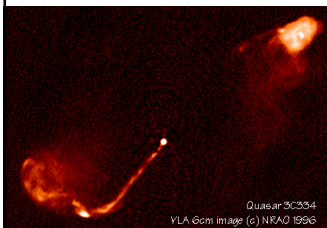
Radio image

Optical image

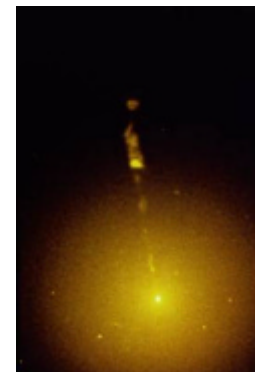• But most are *not* radio sources
 • Quasi-Stellar Objects (QSOs)

[Fig 26.3]

Black Holes

- The mass is so concentrated that light cannot escape from within the Schwarzschild radius of a black hole.
- $R_S = 3$km $M/M_\odot$.
- $R_S = 3$km if $M = M_\odot$.
- $R_S = 3 \times 10^6$km (3 times moon's orbit) if $M = 10^6 M_\odot$.
- $R_S = 3 \times 10^9$km (Saturn's) if $M = 10^9 M_\odot$.

Measurement of Mass of Black Hole

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

1. What must you measure to find the mass of 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
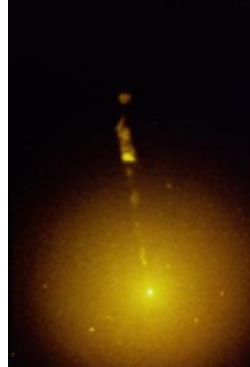
Measurement of Mass of Black Hole

- To find the mass of black hole in M87, a big elliptical galaxy, use Kepler's 3rd Law.
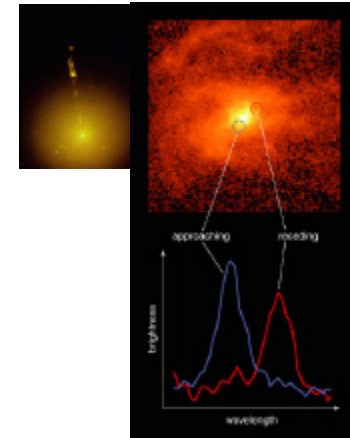
  $Mass = R^3/P^2 = RV^2$

  $R = 60ly$

  $V = 800km/s$
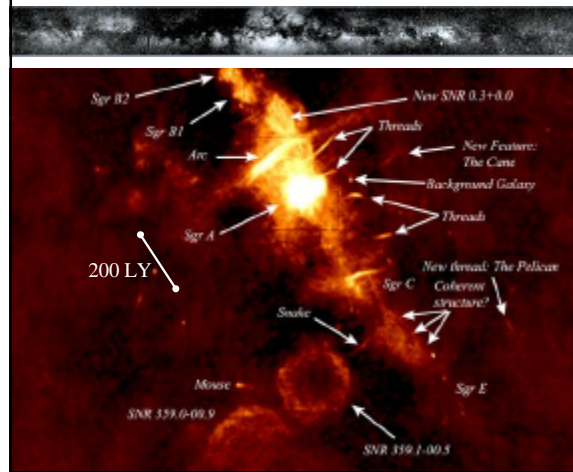
  $M = 3BillionM_\odot$

  $\quad = 3,000,000,000M_\odot$

- If the mass were stars, density is 15,000 times that in sun's neighborhood.

The Center of our Milky Way Galaxy

Visible light

Radio waves

200 LY

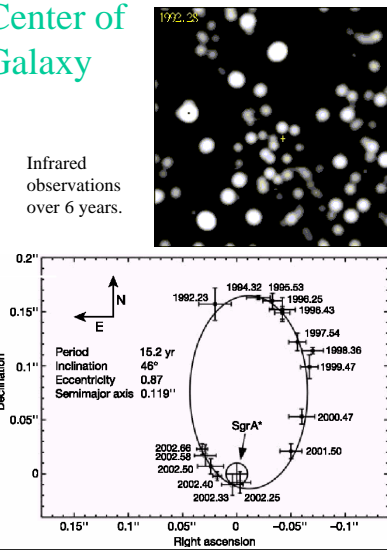## Black Hole at the Center of the Milky Way Galaxy

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

Infrared observations over 6 years.

2. 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

2

Slide 1: Black Hole at the Center of the Milky Way Galaxy

- Orbit is a ellipse tilted by 46°!
    - P=15yr
    - R=900AU
- Data from 2002 goes within 60AU from black hole. [Orbit of Pluto is 40AU.]
- Mass=R^3/P^2
    =3,000,000M⊙
- Within 60AU, the mass at SgrA* acts like a point.

Infrared observations over 6 years.

Period   15.2 yr
Inclination   46°
Eccentricity   0.87
Semimajor axis   0.119''

Slide 2

The Source of the Luminosity:

• Matter falls onto accretion disk.

• Disk heats up & glows.

Black Hole

Slide 3

Cen A

Nearby Radio Galaxies.
• Elliptical Galaxies.

Also… Seyfert Galaxies
• Spiral galaxies with very low-luminosity quasar at center.

The Leftovers:
Active Galaxies

M 87

3C 219

Cygnus A

Slide 4

GO STATE