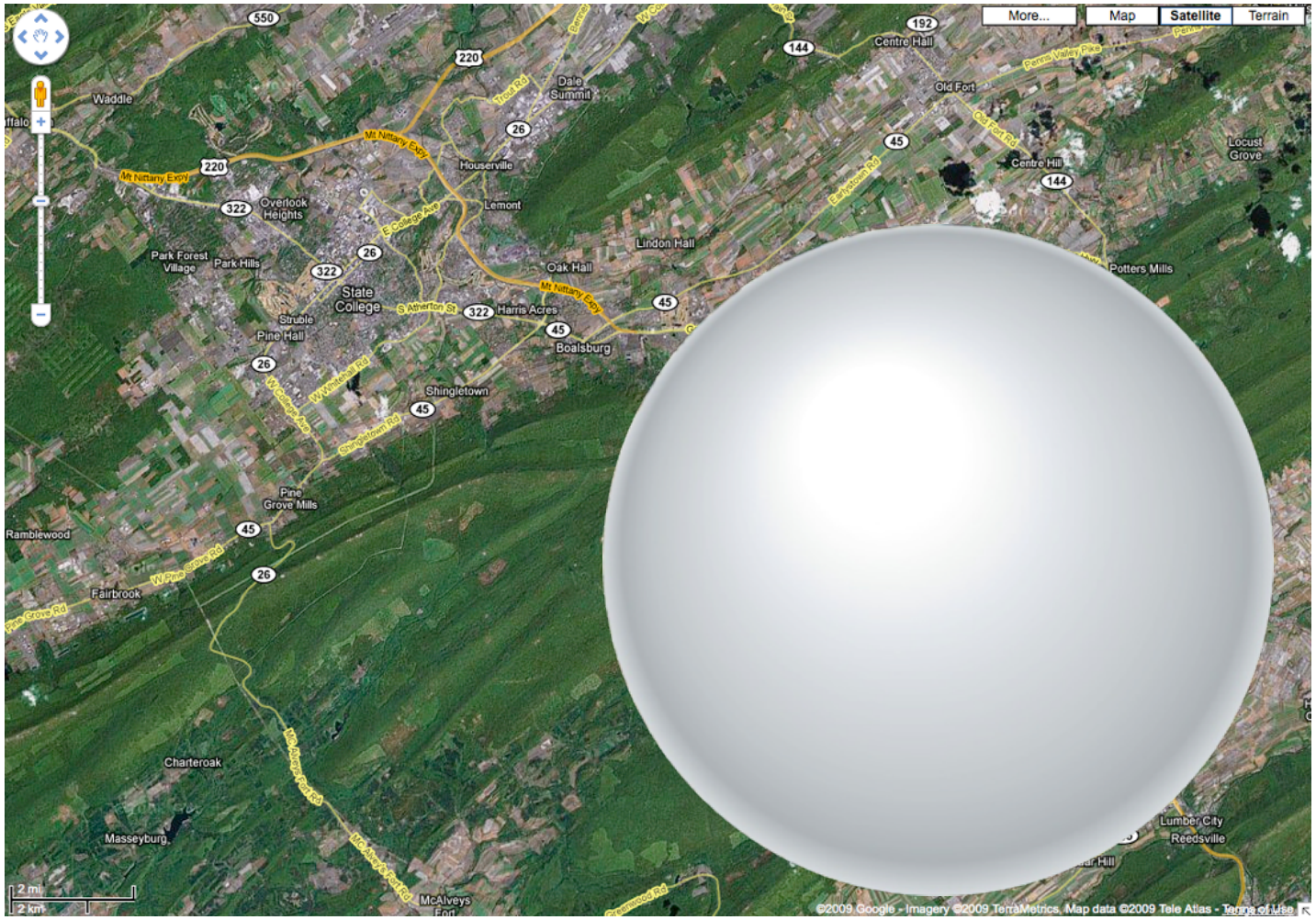

QuickTime™ and a
decompressor
are needed to see this picture.

# Lecture 21 - 16 April 2009

**HOMEWORK 8: due next Tuesday, 21 April, 11:59pm**

- **SCIENCE TOPICS**:
  Black Holes
  Galaxies
- **READING**
  Ch. 13 Sec. 13.5-13.8
  Ch.14, sec 14.1, 14.3, 14.6
- **PRACTICE: Ch 13**
  Review: 12, 13
  Self-Test: 4, 6, 12
- **PRACTICE: Ch 14**
  Review: 7, 11–14
  Self-test: 3–6, 9,12, 13, 15

# Neutron Star vs. State College



# Black Holes

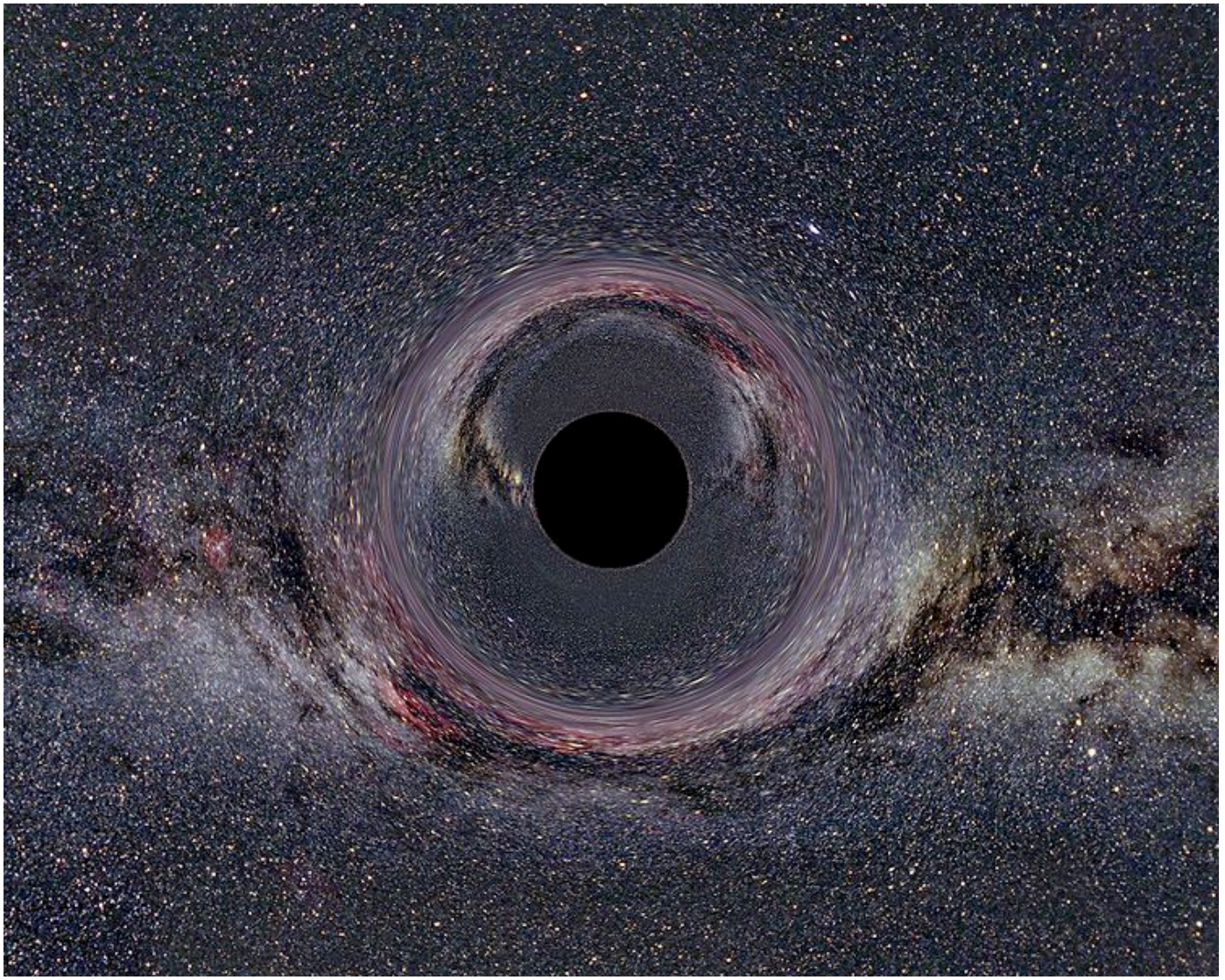
## ... are *weird*

# Escape Velocity

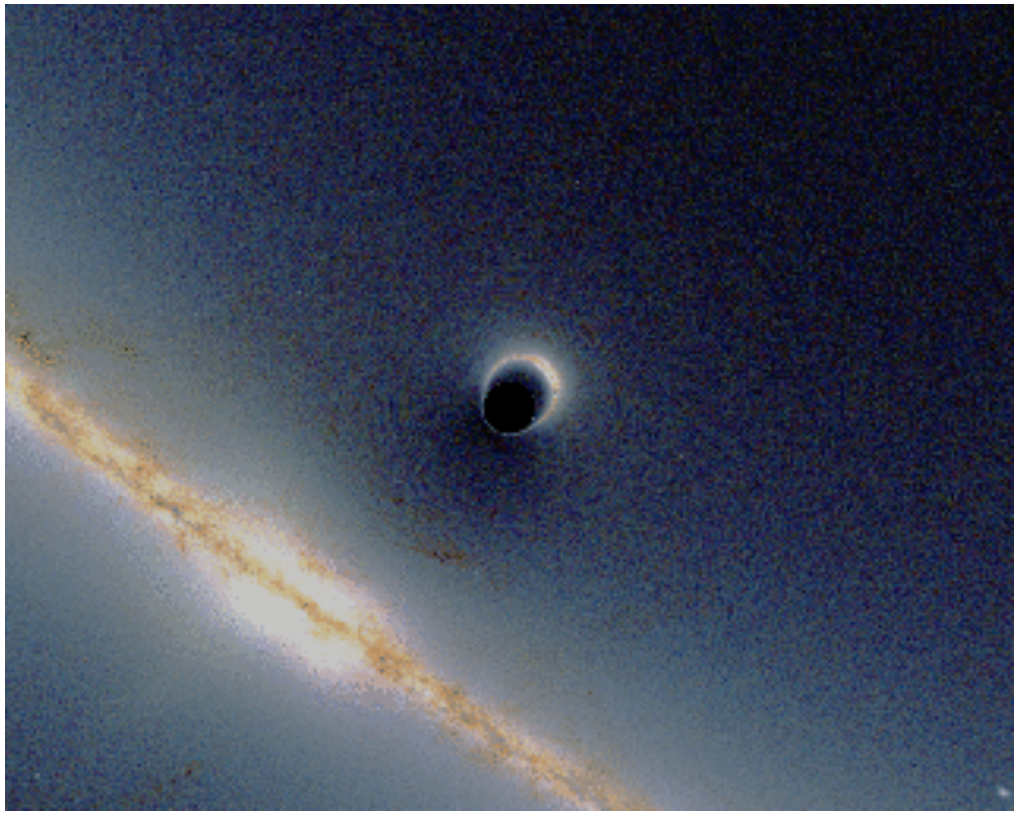
# Black Holes have no hair...

- **Mass**
- **Charge (but mostly neutral)**
- **Angular Momentum (“spin”)**

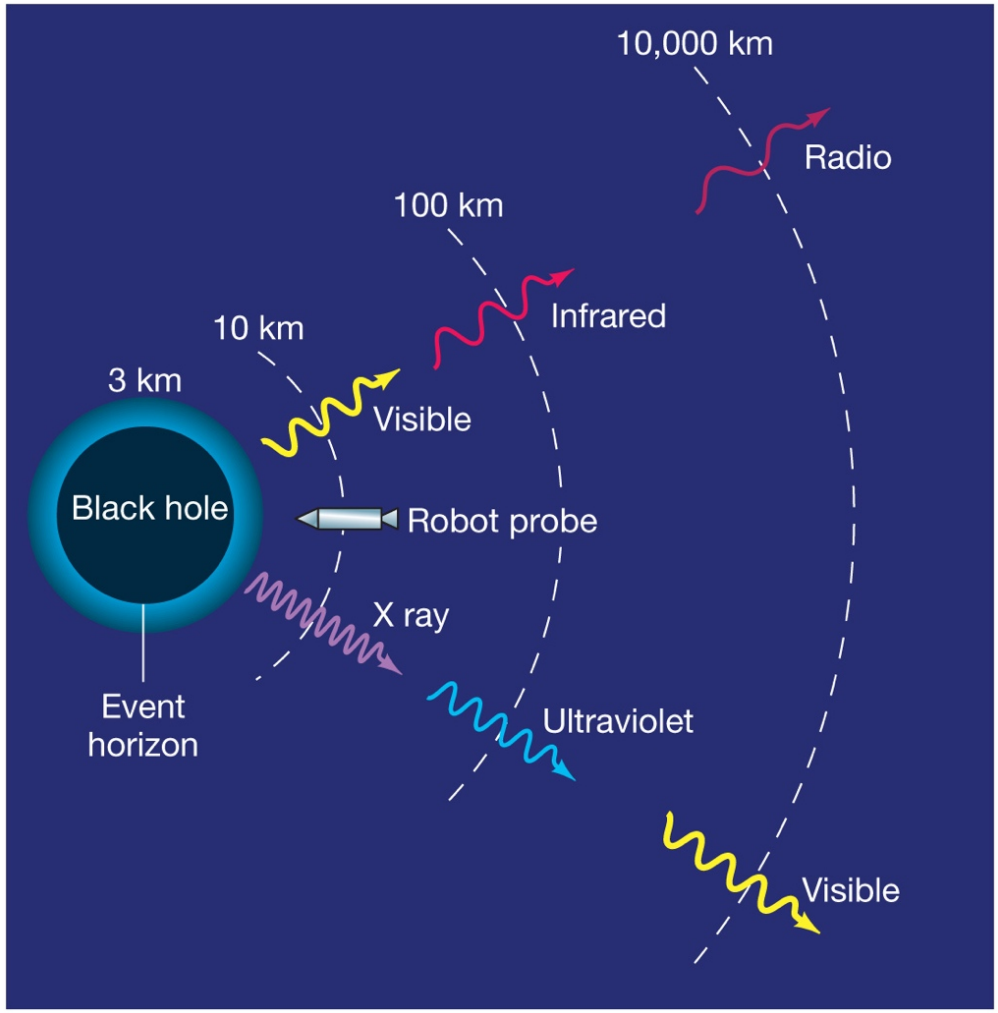
# Gravitational Lensing



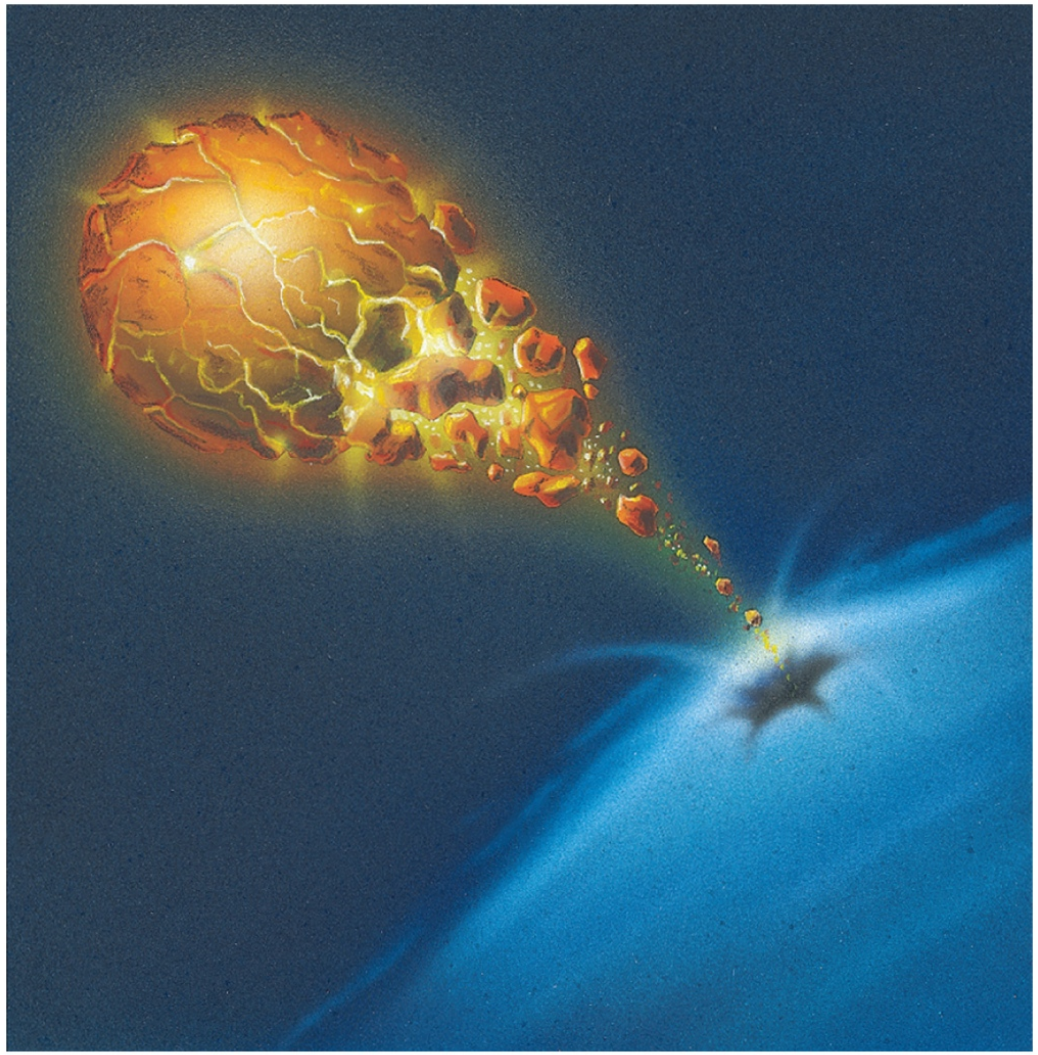
# Gravitational Lensing

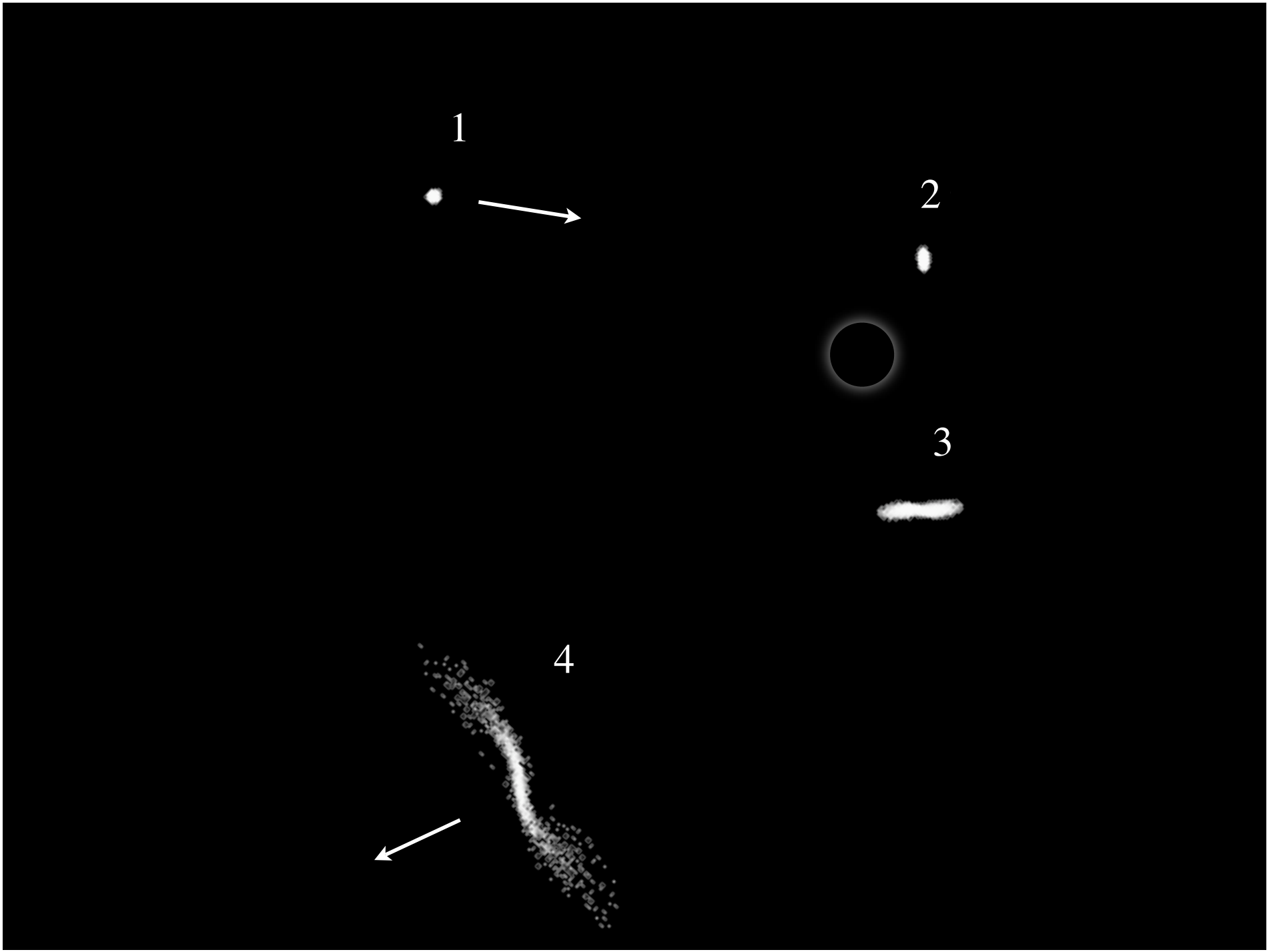


# Gravitational Redshift



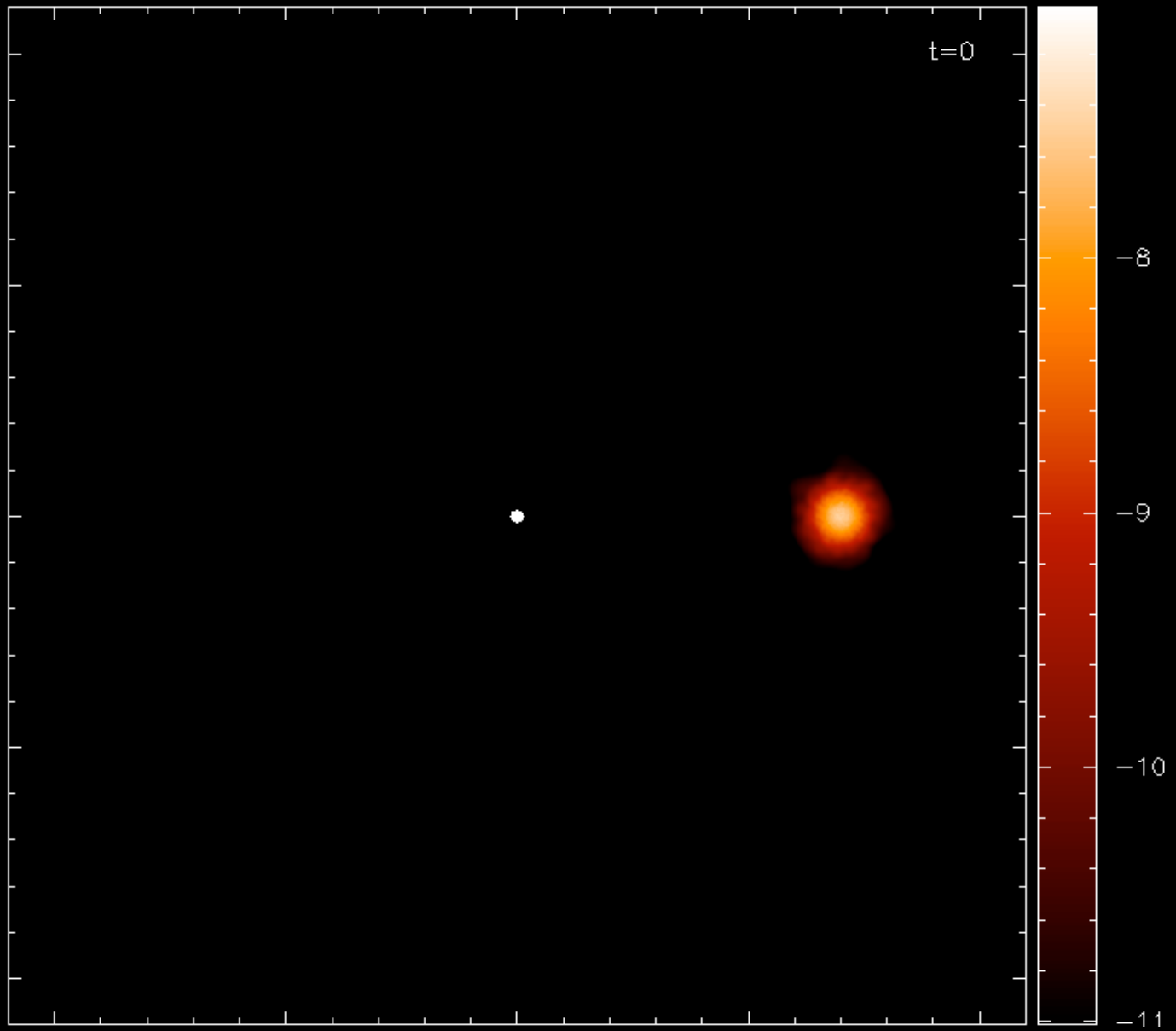
# Strong Tidal Forces



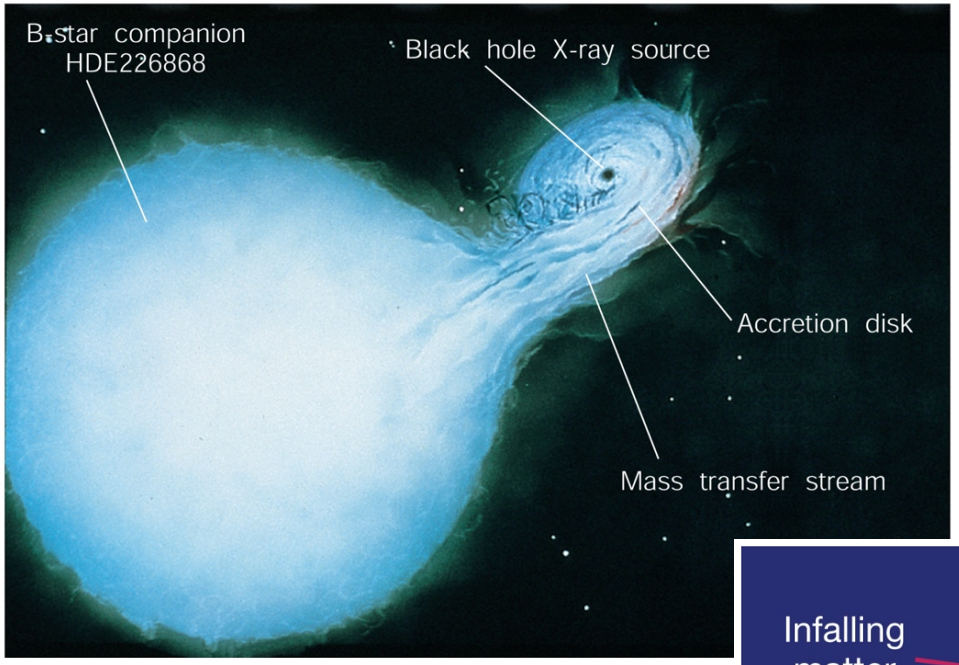

1
2
3
4

# White Dwarf in Bound Orbit Around a Black Hole

Simulation by
D. Clausen,
(Penn State)

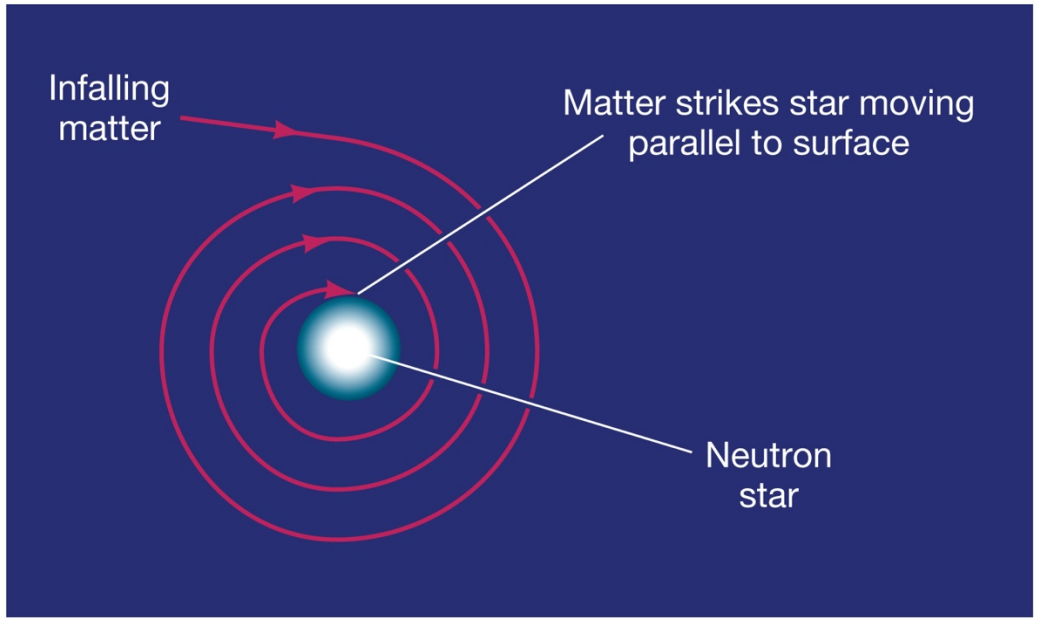


# Accretion and Accretion Disks



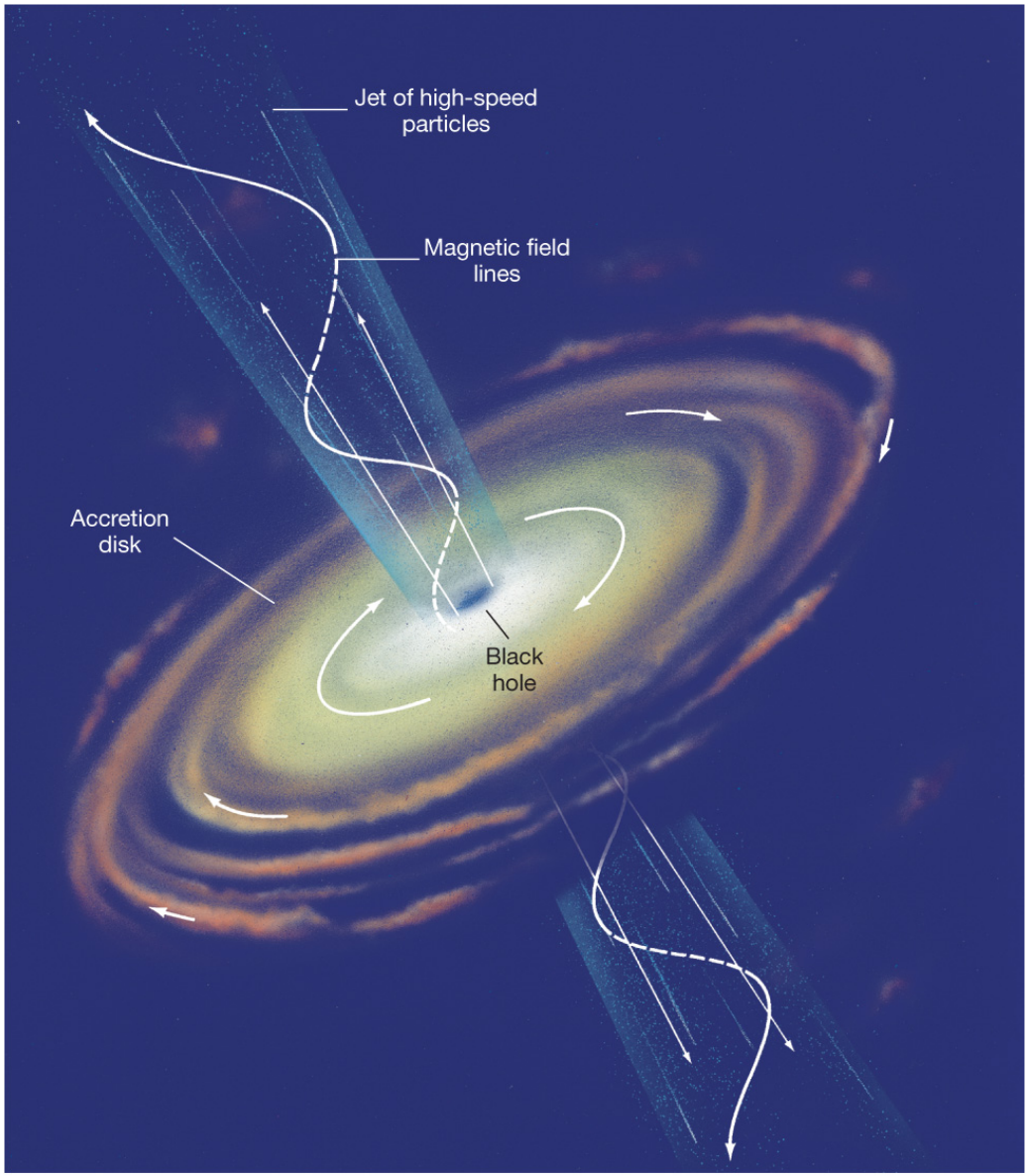


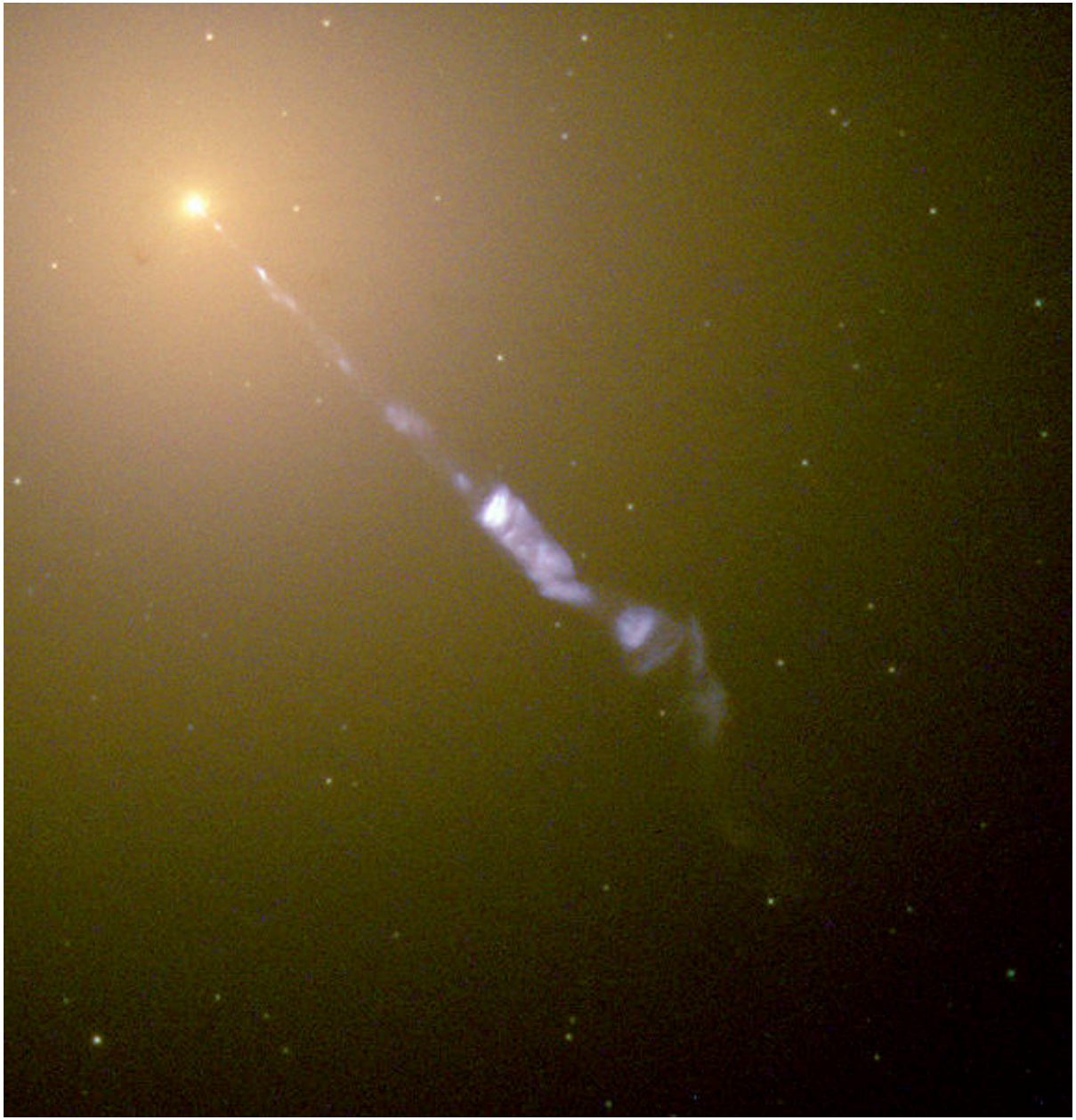

Cygnus X-1



# (Currently) Two types of Black Holes

- **Solar Mass**
  - Remnants of massive stars, found in our own Milky Way galaxy
- **Supermassive**
  - $10^6$ - $10^9$ solar masses, found at the centers of galaxies, incl. the MW.





# M87 (with *HST*)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