

# Quasars and Jets

- Quasi-stellar objects
  - Redshifts
  - Variability
  - Supermassive black holes
- Black hole jets
  - Acceleration and Collimation
  - Superluminal motion
  - Evolution of jets

The maximum luminosity for an accreting black hole is the luminosity

- A) of a main sequence star of the same mass
- B) at which radiation pressure equals gravitation force for infalling matter
- C) at which magnetic pressure equals gravitation force for infalling matter
- D) produced when Sir Arthur Eddington is dropped into the hole

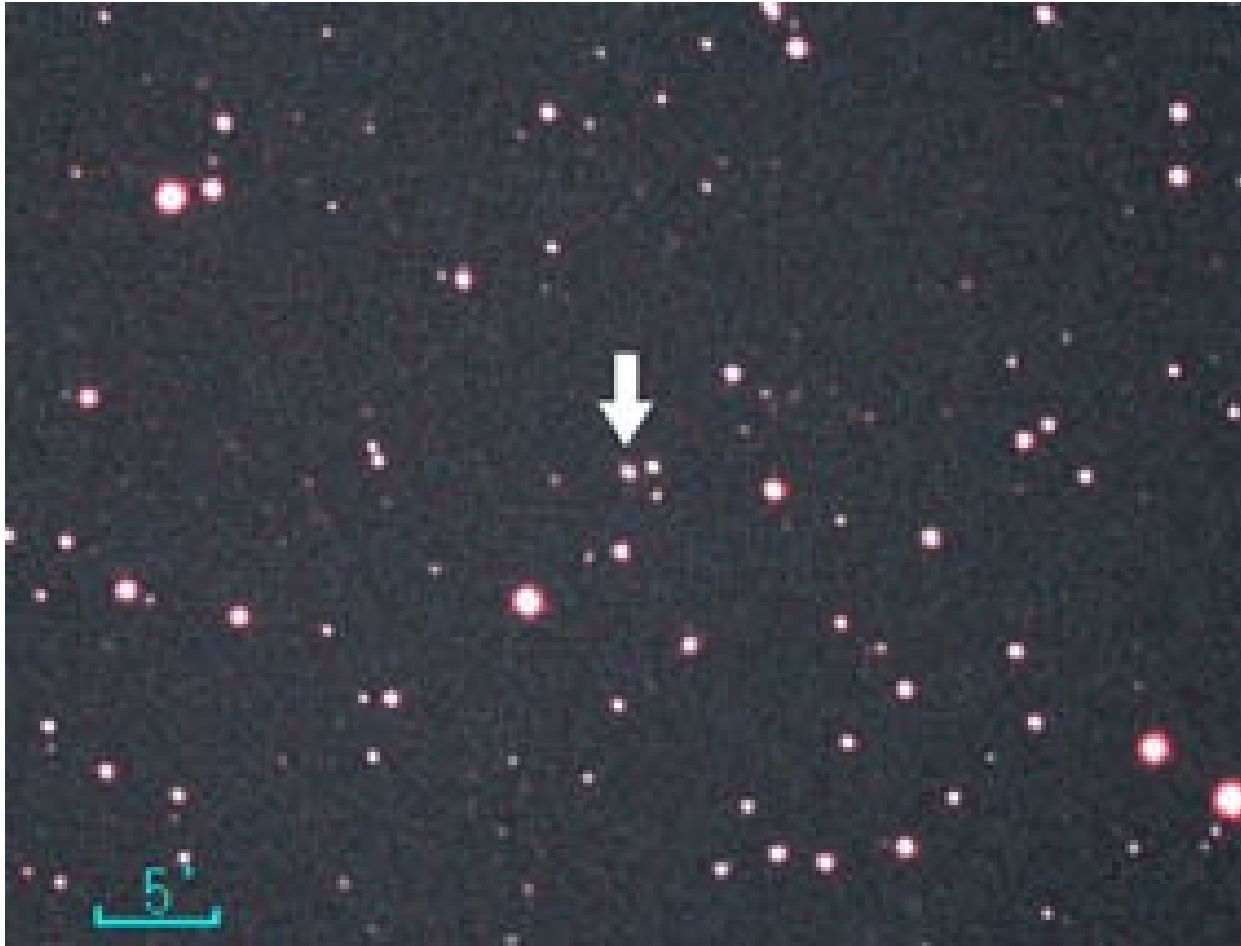
# Quasars

- Early radio telescopes found radio emission from stars, nebulae, and some galaxies.
- There were also point-like, or star-like, radio sources which varied rapidly these are the 'quasi-stellar' radio sources or quasars.
- In visible light quasars appear as points, like stars.

Optical  
picture of a  
quasar



# 3C273

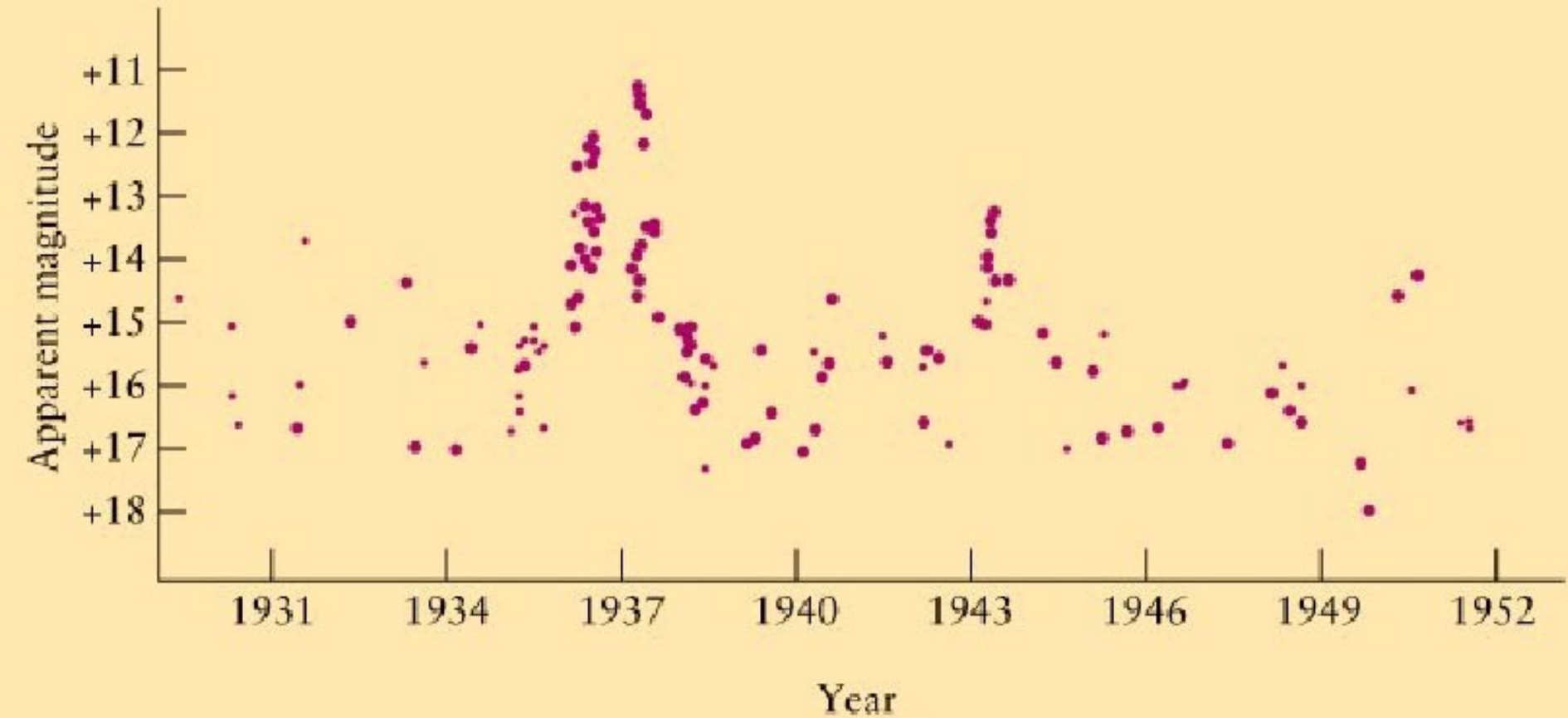


The quasar 3C273 is 2.6 billion light years away.

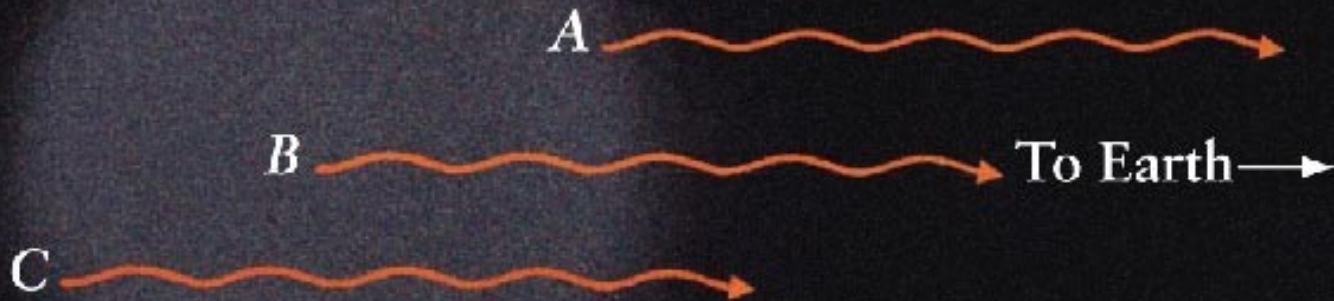
It looks dim, but must be extremely luminous to be visible as such distance.

The luminosity of 3C273 is more than one trillion times the entire energy output of our Sun, or 100 times the luminosity of our entire galaxy.

# Quasars vary



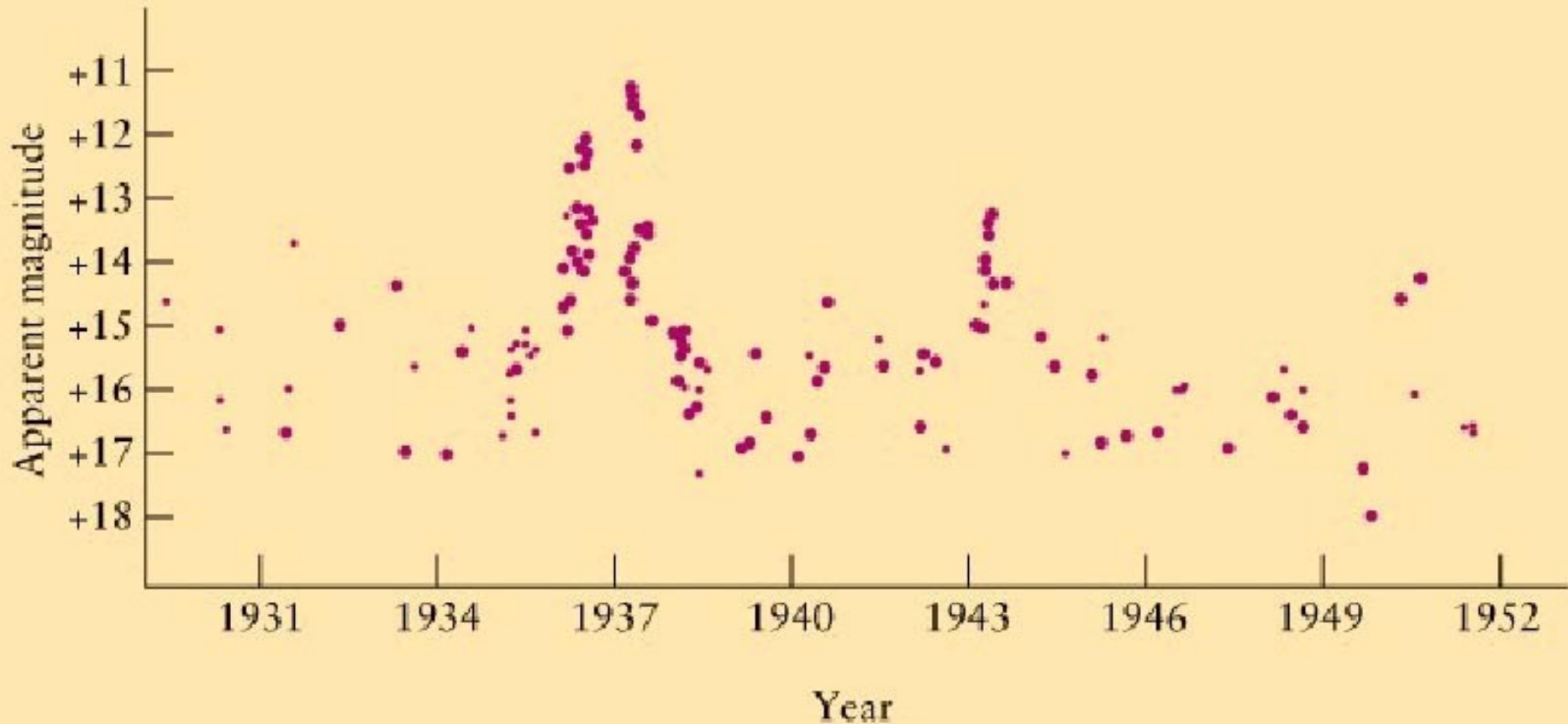
# Quasar size



Size places a limit on how fast an object can change brightness.

Conversely, rapid variations place a limit on the size of the emitting object.

# Quasars vary



The size of this quasar must be less than about one light year.



# Quasar engine

- Quasars have 100 times the luminosity of our Galaxy
- The engine powering quasars is at most a few light years across
- **The only known engine which is powerful enough and compact enough is a black hole**
- Quasars contain supermassive black holes

A quasar varies in brightness by a factor of 2 in 10 days. What does this tell us about the quasar?

- A) It has a large magnetic field.
- B) It is quite small.
- C) It must be highly luminous.
- D) It cannot emit radio waves.

The luminosity of a quasar varies by a factor of 10 over 1 day. What does this tell us about the power source?

- A) It cannot be less than 1 light day in diameter
- B) It cannot be less than 10 light days in diameter
- C) It cannot be more than 1 light day in diameter
- D) It cannot be more than 10 light days in diameter
- E) It cannot make up its mind

# Quasar jets

Optical core →

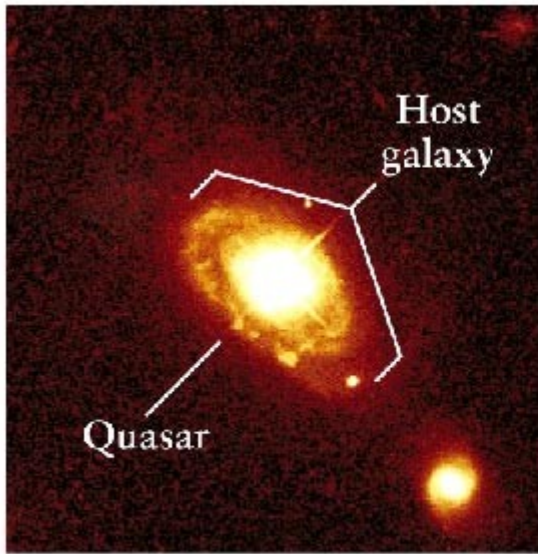
Radio jet →



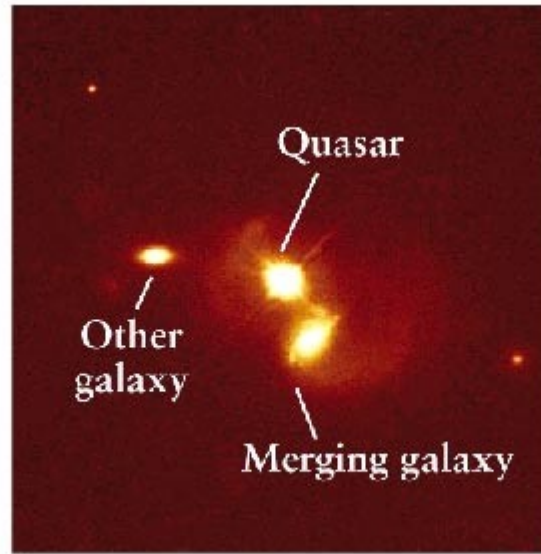
# Quasars

- object with a spectrum much like a dim star
- high red shift
- enormous recessional velocity
- huge distance (from Hubble's Law)
- enormously luminous
- compact physical size
- powered by supermassive black hole
- often produce huge jets

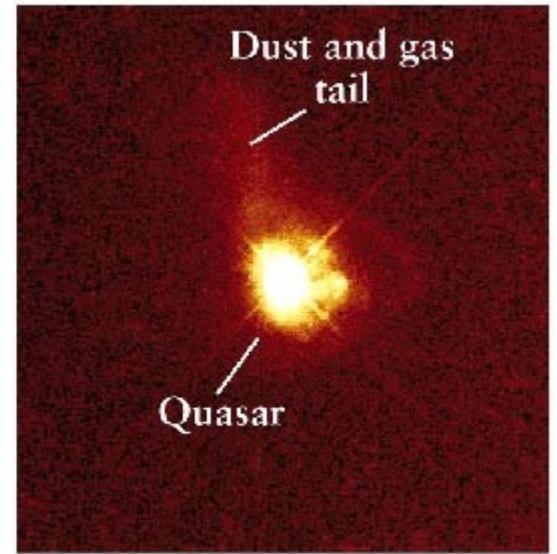
# Quasars are the ultraluminous centers of distant galaxies.



a



b



c

*Quasars are often observed to be at the center of distant galaxies. The wispy material is likely gas that has been pulled out of the hot galaxy by gravitational interactions with nearby galaxies.*

What is the radius of a 100 million solar mass black hole (non-rotating) such as those that exist at the centers of some quasars?

- A) 10 km (neutron star)
- B) 6000 km (Earth)
- C)  $1.5 \times 10^8$  km (AU)
- D)  $10^{13}$  km (light year)

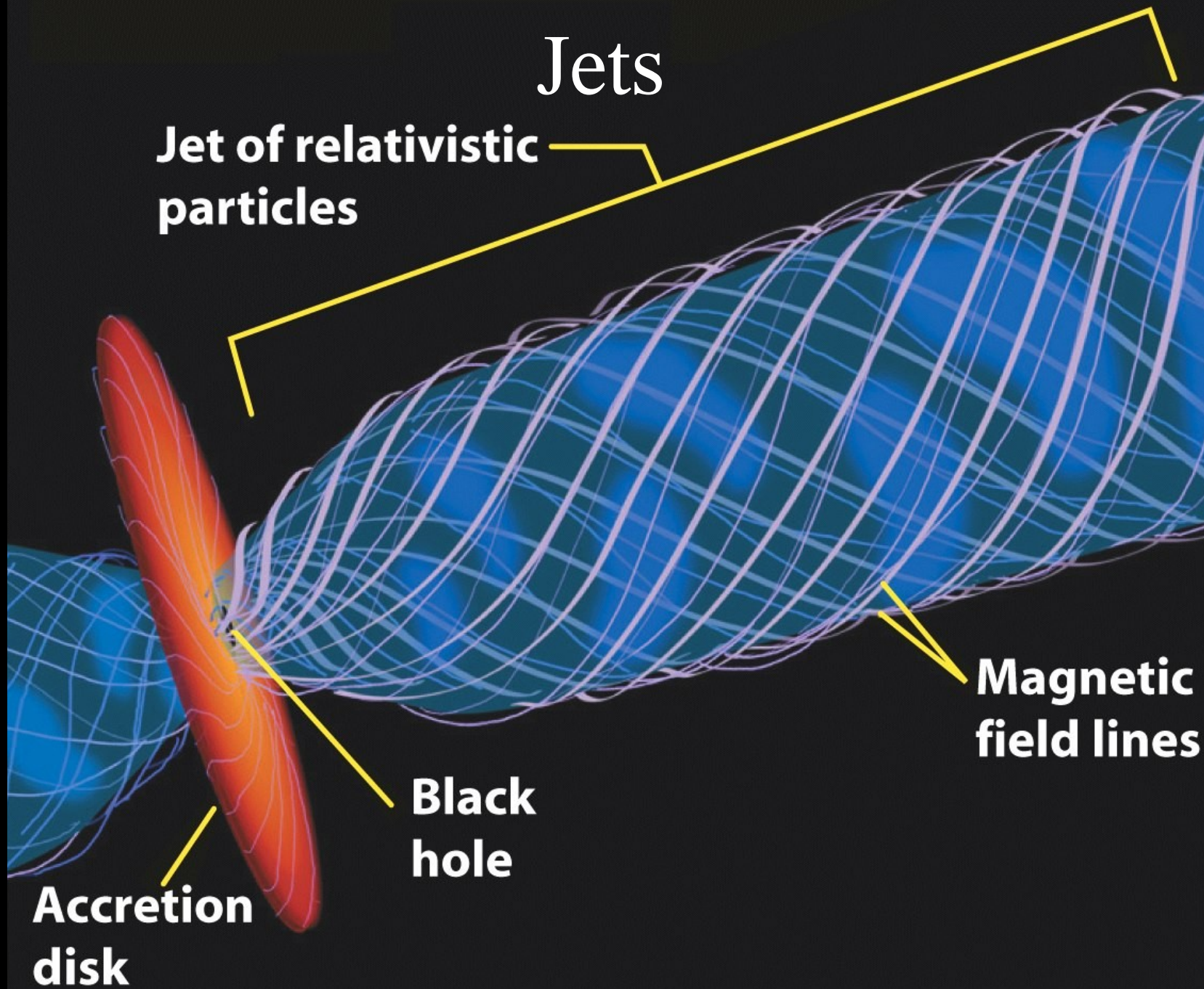
$$\text{Schwarzschild radius} = 3 \text{ km } (M/M_{\text{Sun}})$$

# Jets

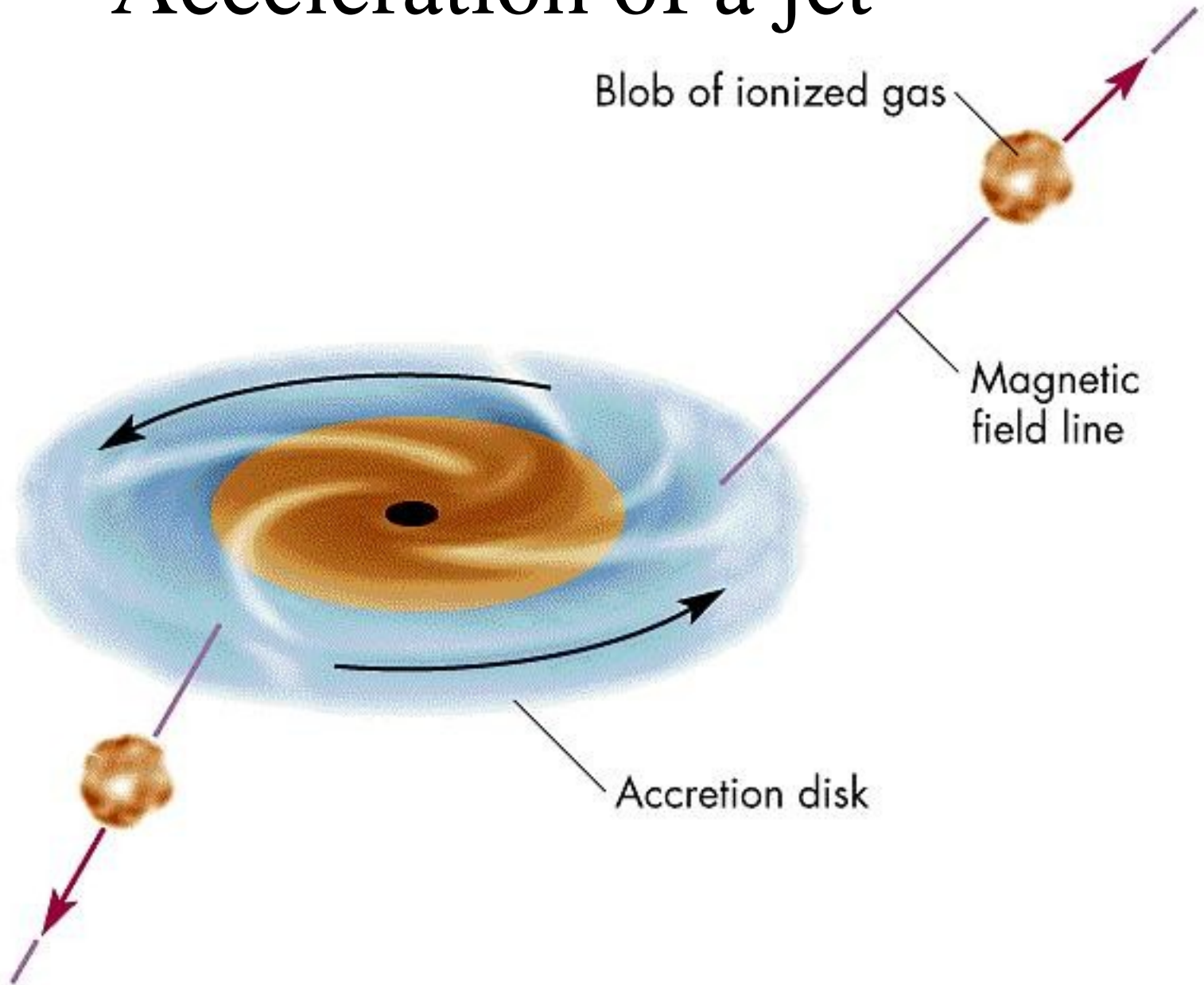


| -- Size of our Galaxy -- |

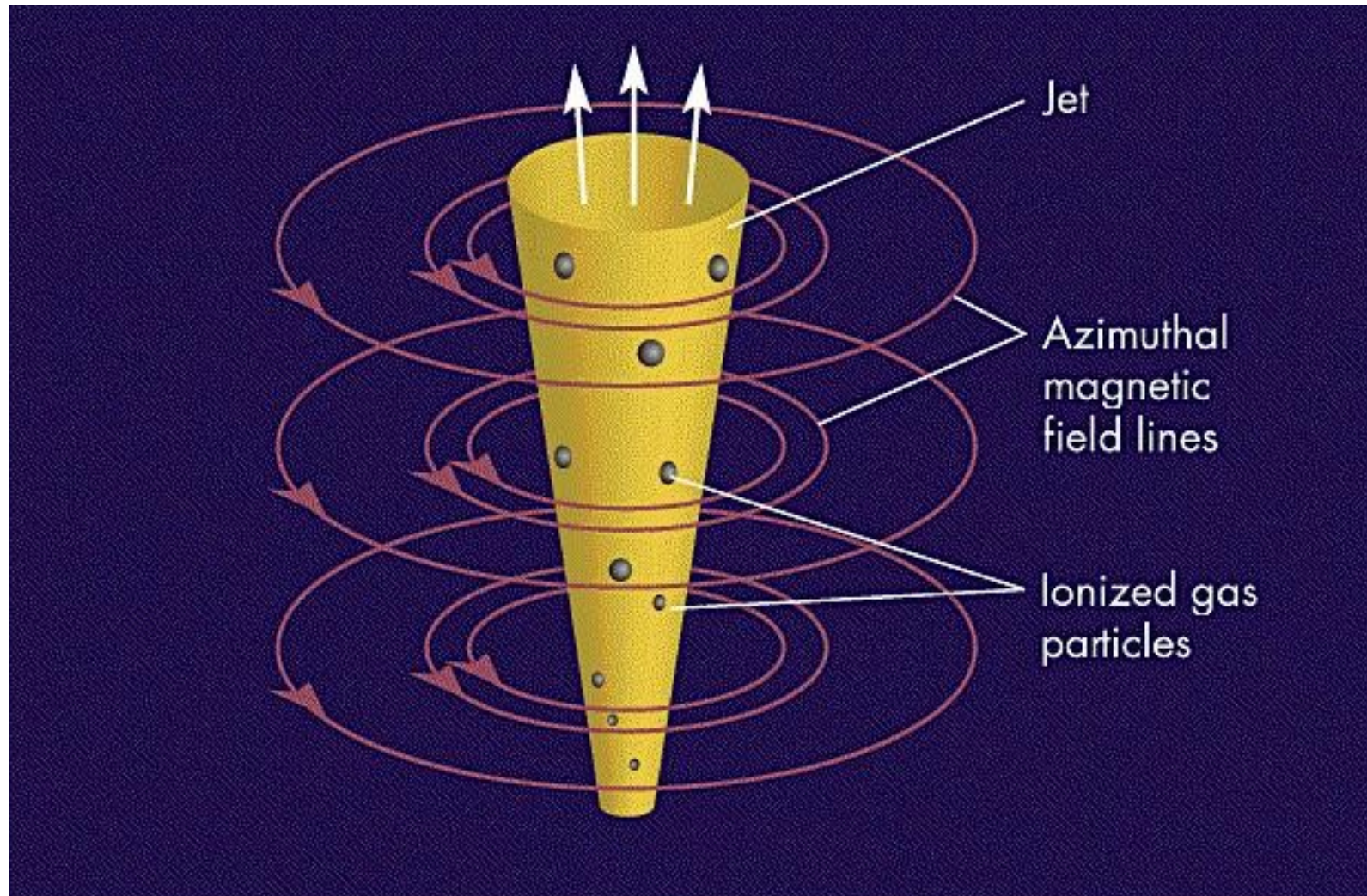




# Acceleration of a jet



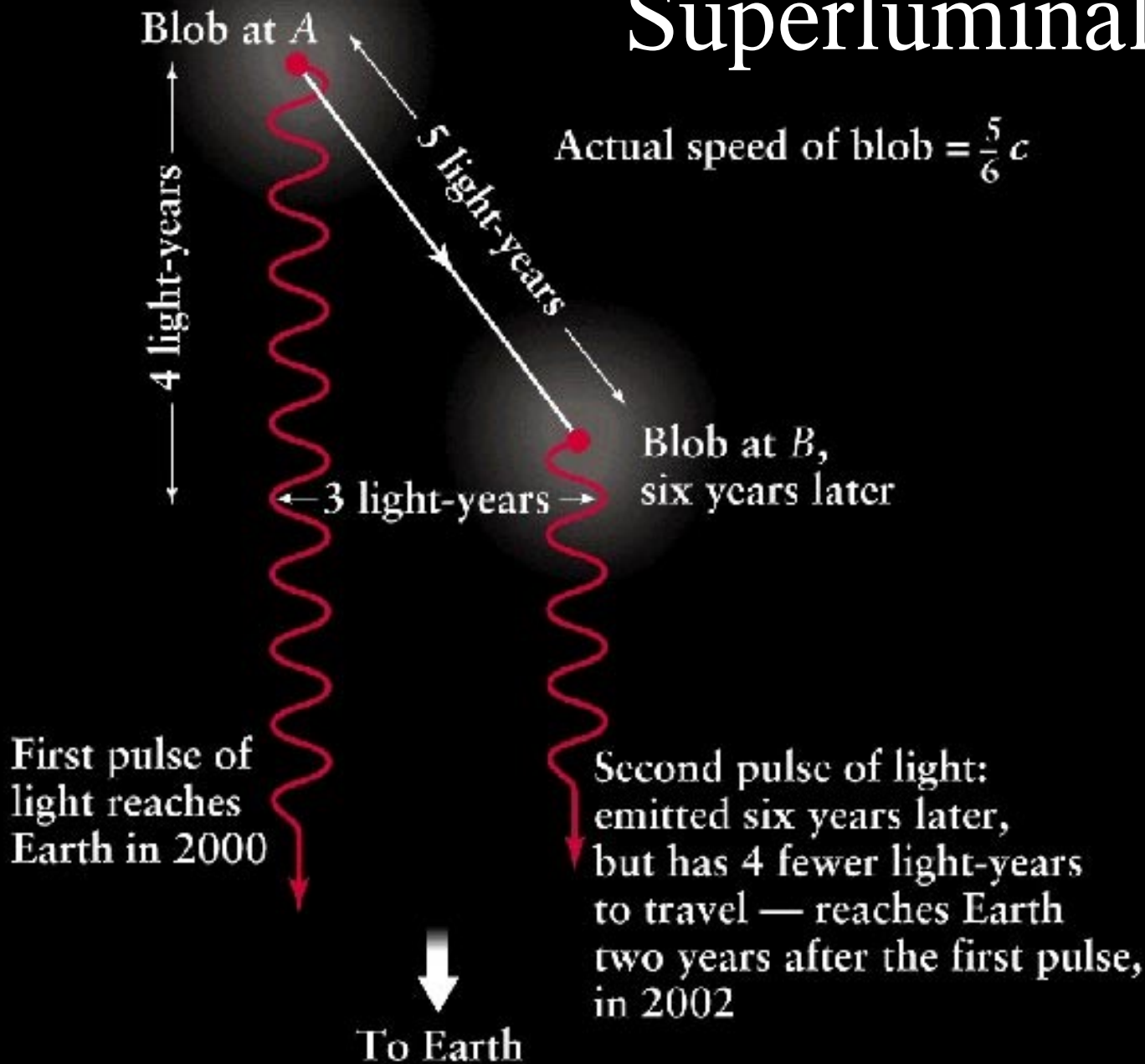
# Collimation of a jet



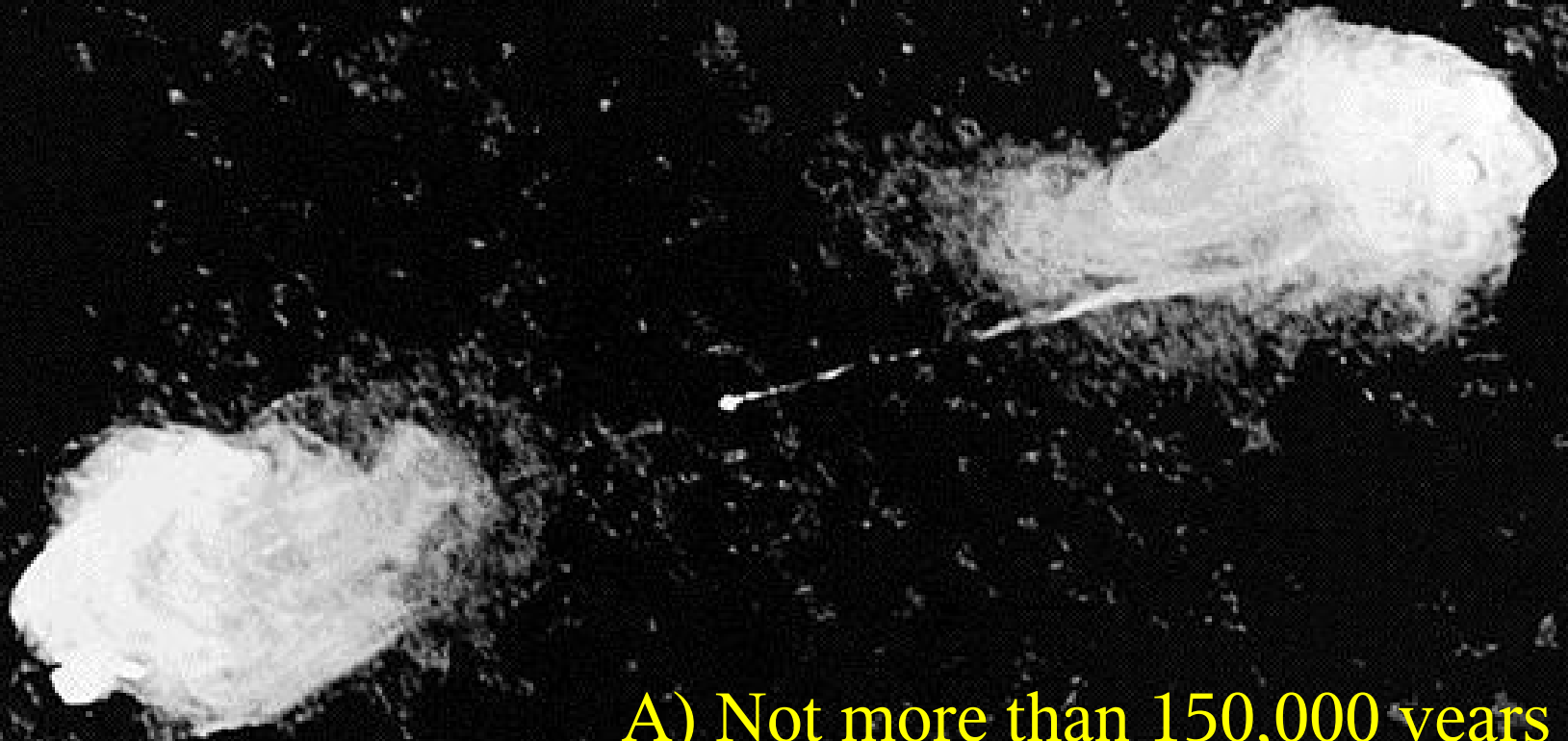
# Origin of jets is an unsolved problem

- The production and propagation of jets is a major topic in current research.

# Superluminal motion



# What is the lifetime of this jet?



- A) Not more than 150,000 years
- B) Exactly 150,000 years
- C) At least 150,000 years

| ----- | = 150,000 light years

# Evolution of Jets

- Jets from active galaxies are large and change slowly.
- Jets from solar-mass black holes are smaller, by the ratio of the black hole masses, and change more rapidly.
- It is possible to study the evolution of jets from solar-mass black hole.
- Show [movie](#) and then [animation](#).

# Review Questions

- How can we place an upper bound on the size of a quasar even if we can't resolve it with a telescope?
- How are jets accelerated?
- How are jets collimated?
- Do superluminal jets really move faster than the speed of light?
- Do the jets of stellar-mass black holes evolve faster or slower than the jets of supermassive black holes?