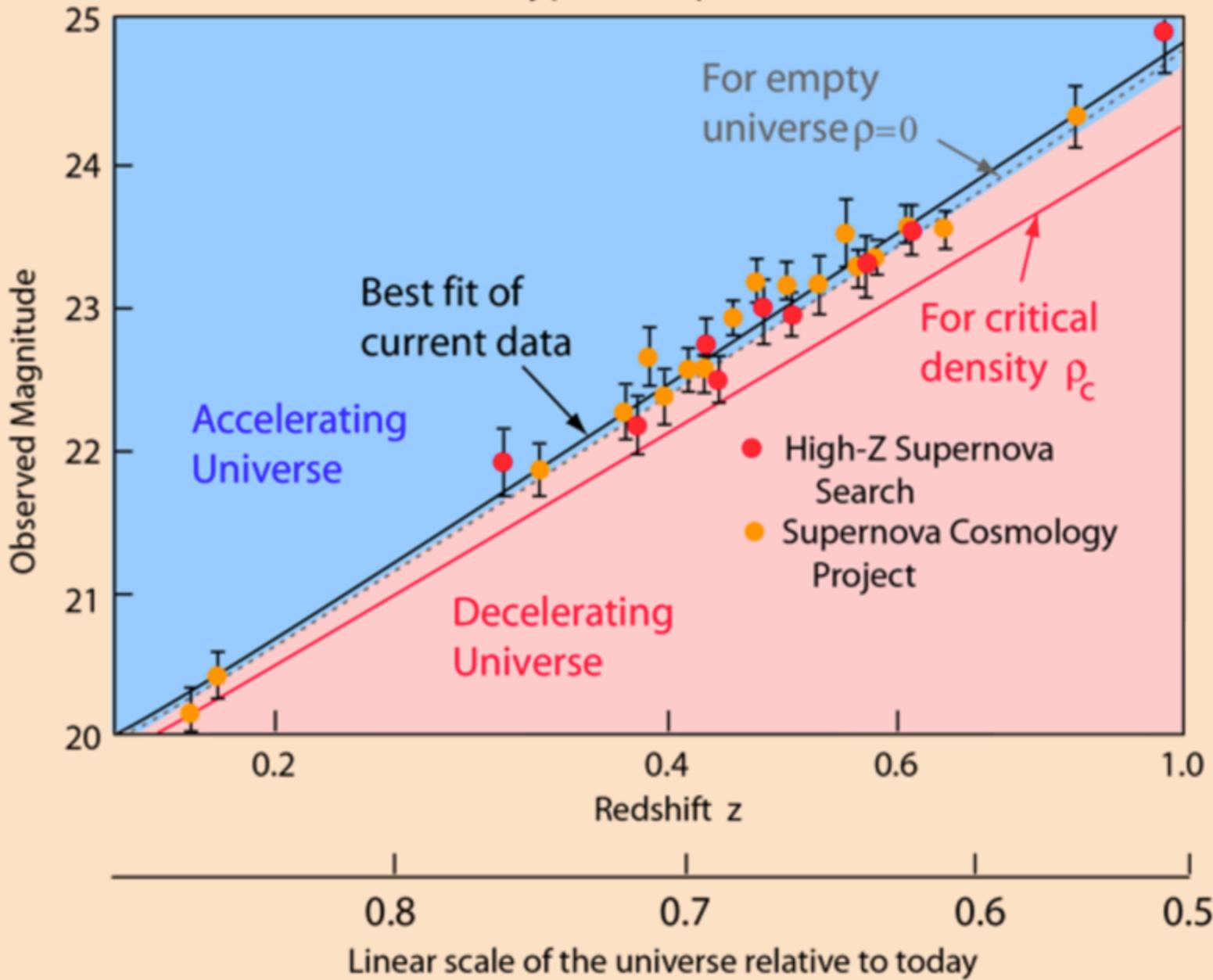
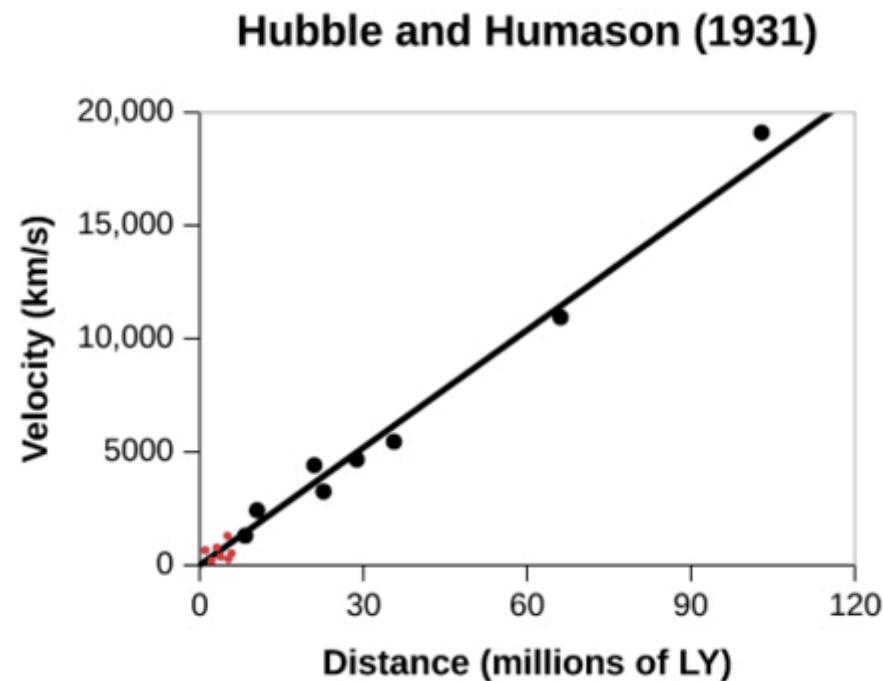
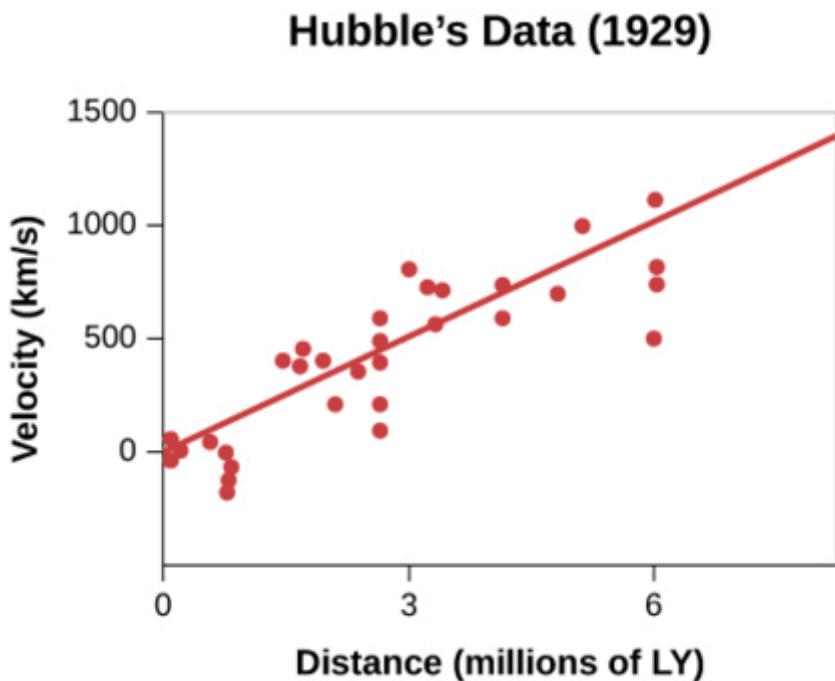


## Distant Type Ia Supernovae



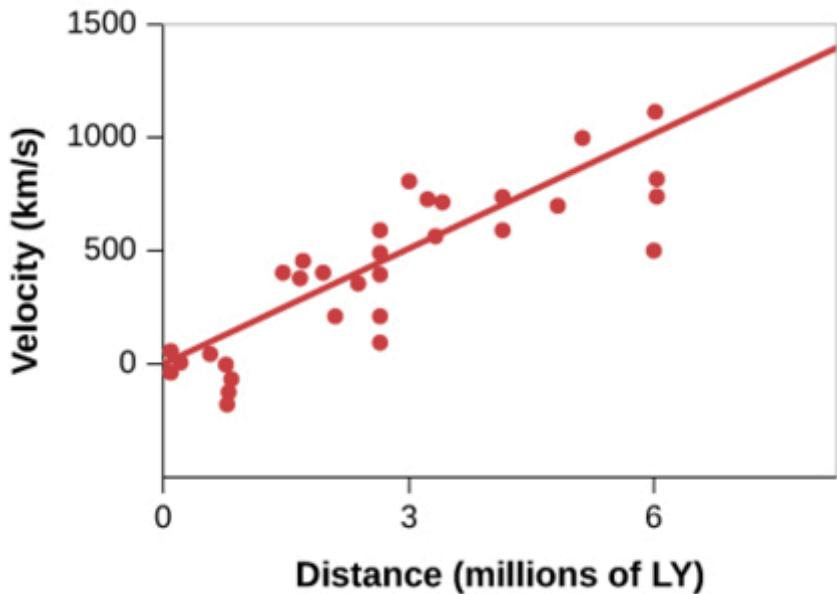
Hubble's Law: distance proportional to redshift  
Redshift: spectrum of light shifted to red (going away from us)



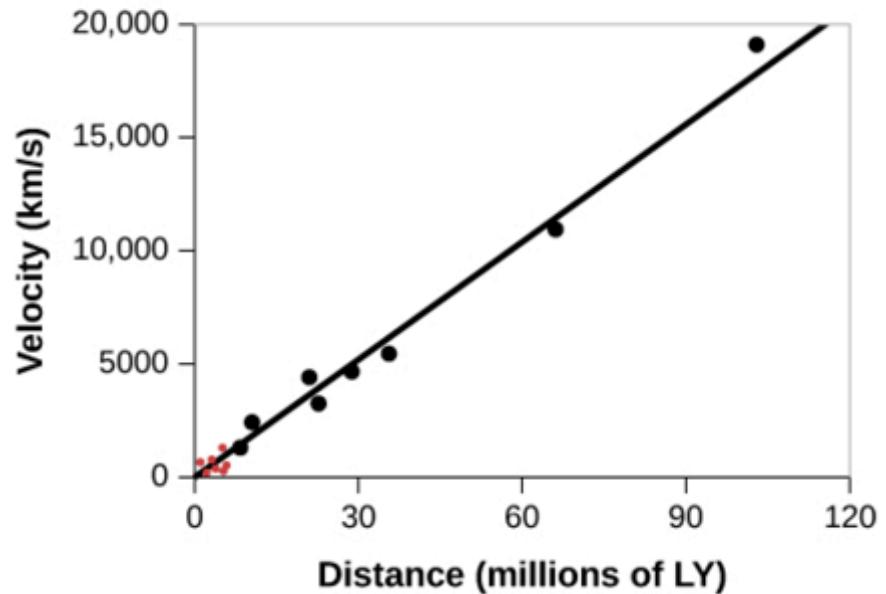
$$V = H \times d$$

When we look at larger distances,  
we are looking into the past!

Hubble's Data (1929)

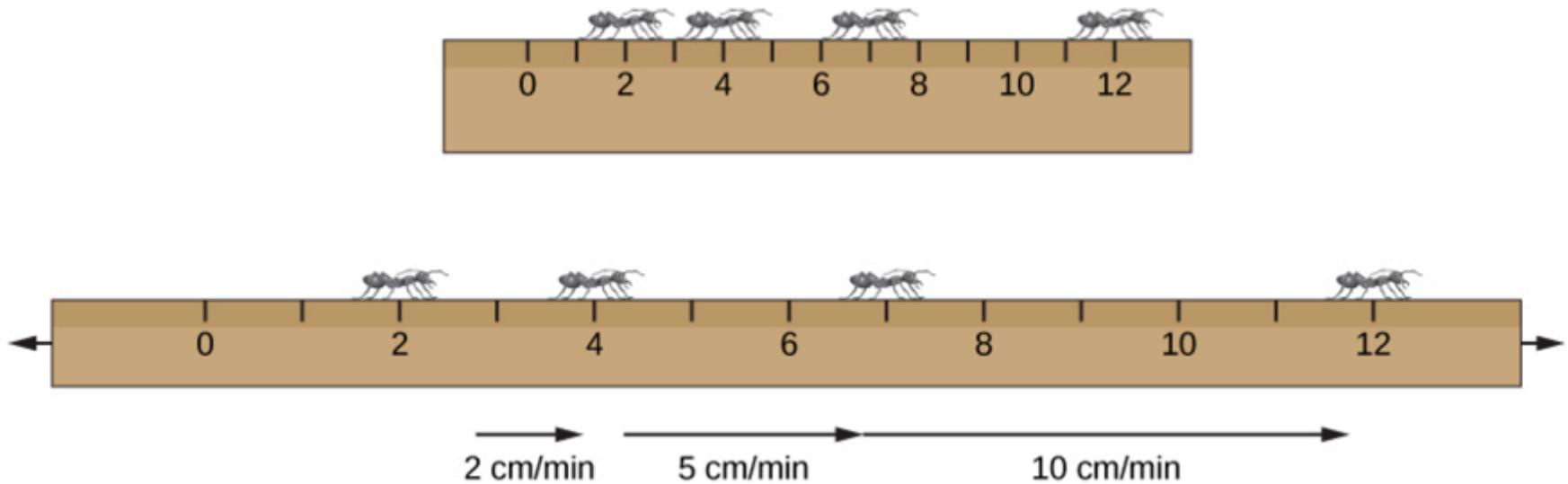


Hubble and Humason (1931)



$$V = H \times d$$

# Expansion of universe



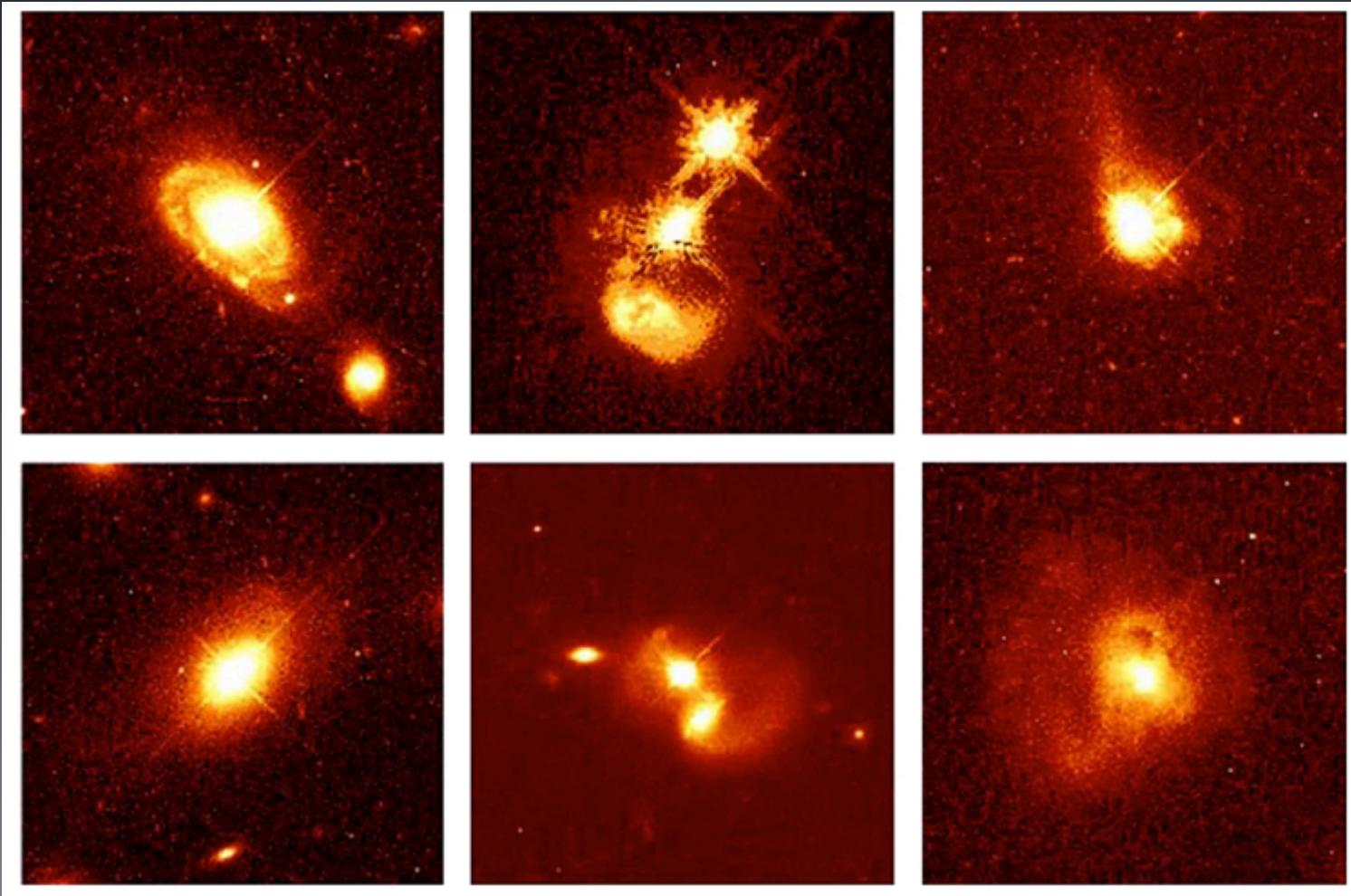
More in 2 weeks

# Supermassive black holes!

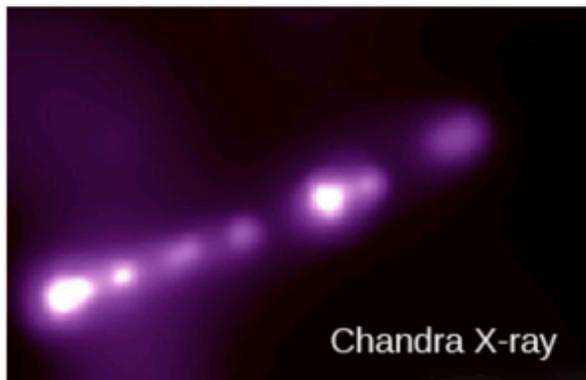
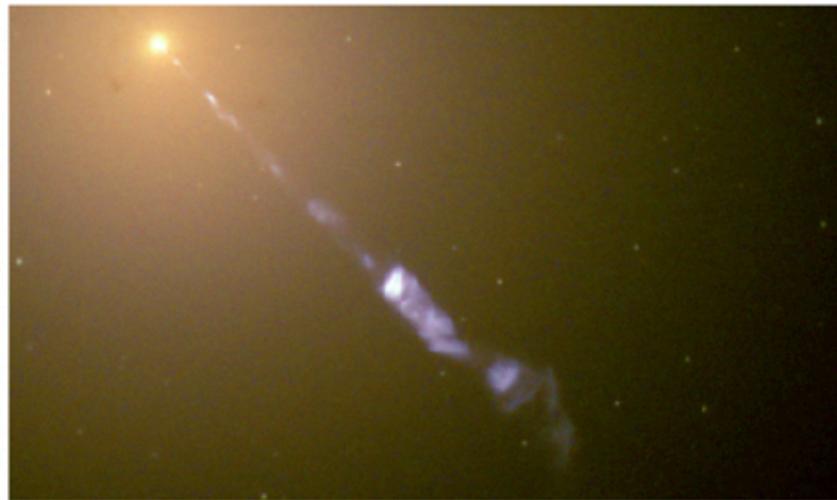
## Quasars: quasi-stellar objects



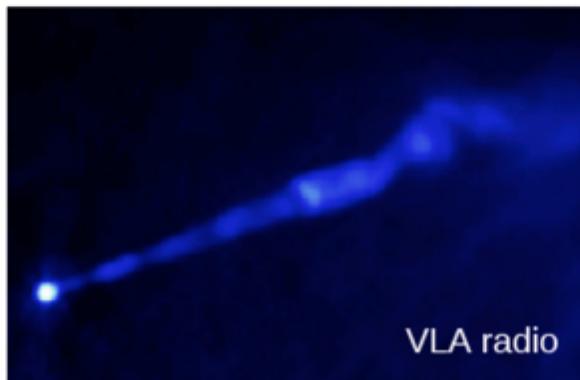
Quasars: accreting gas, outshines their host galaxies (but they do have host galaxies)



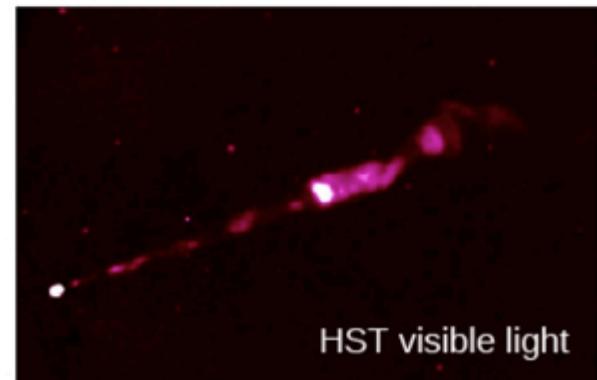
# Jets from the central black hole



Chandra X-ray

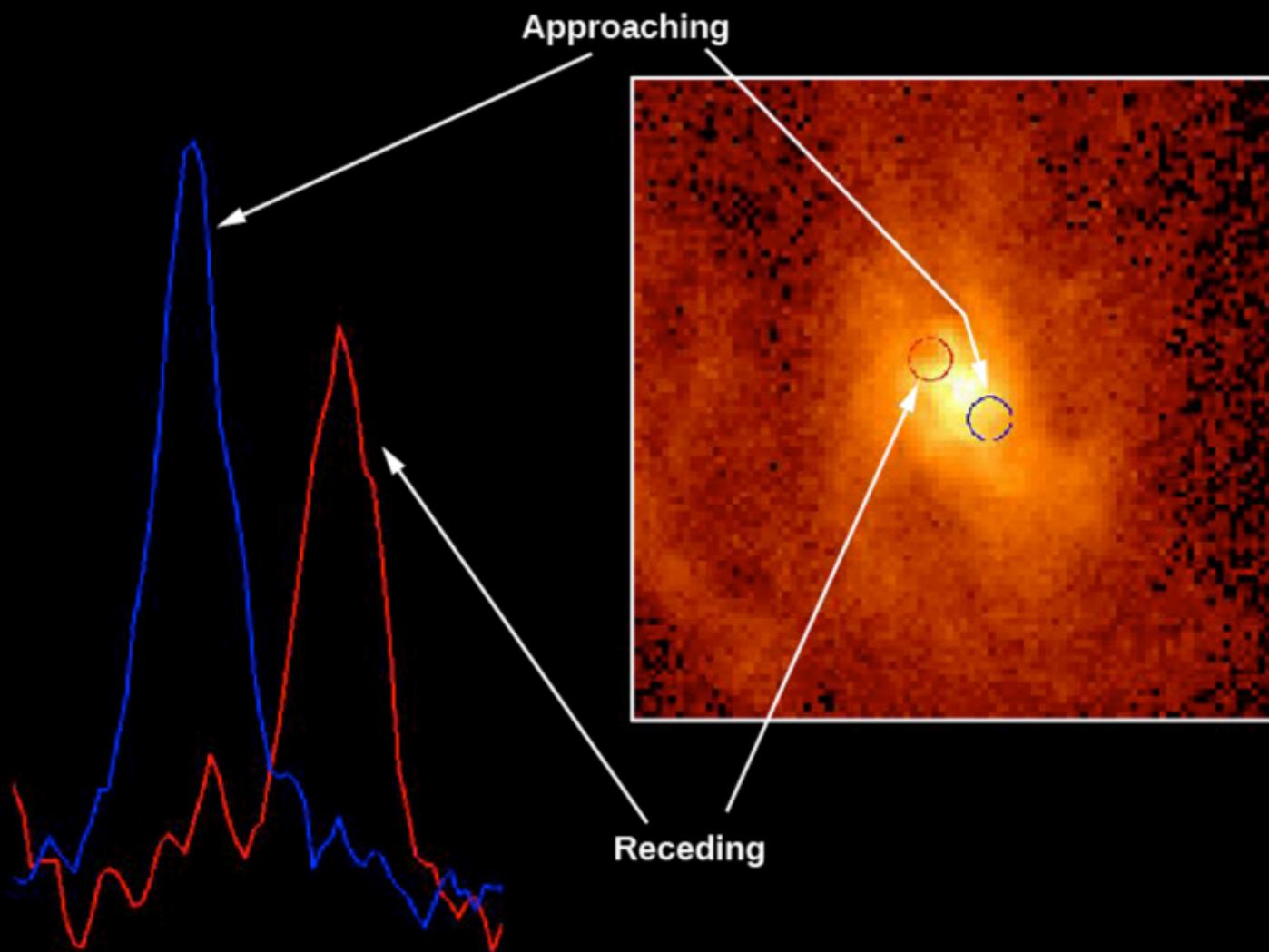


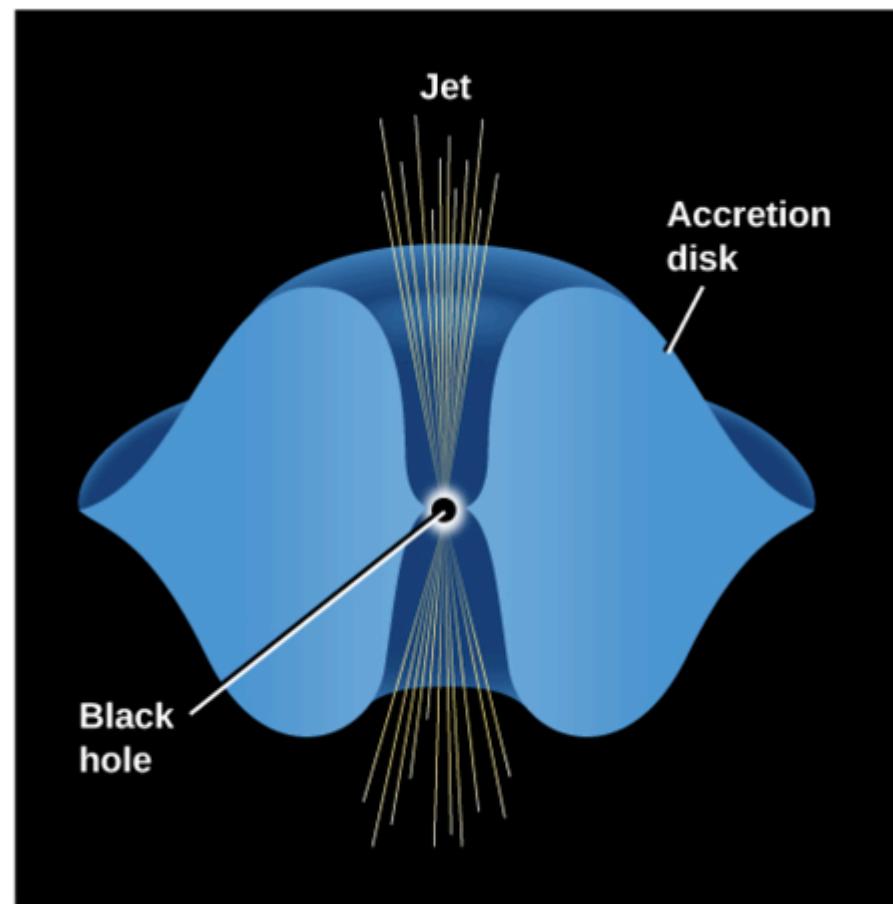
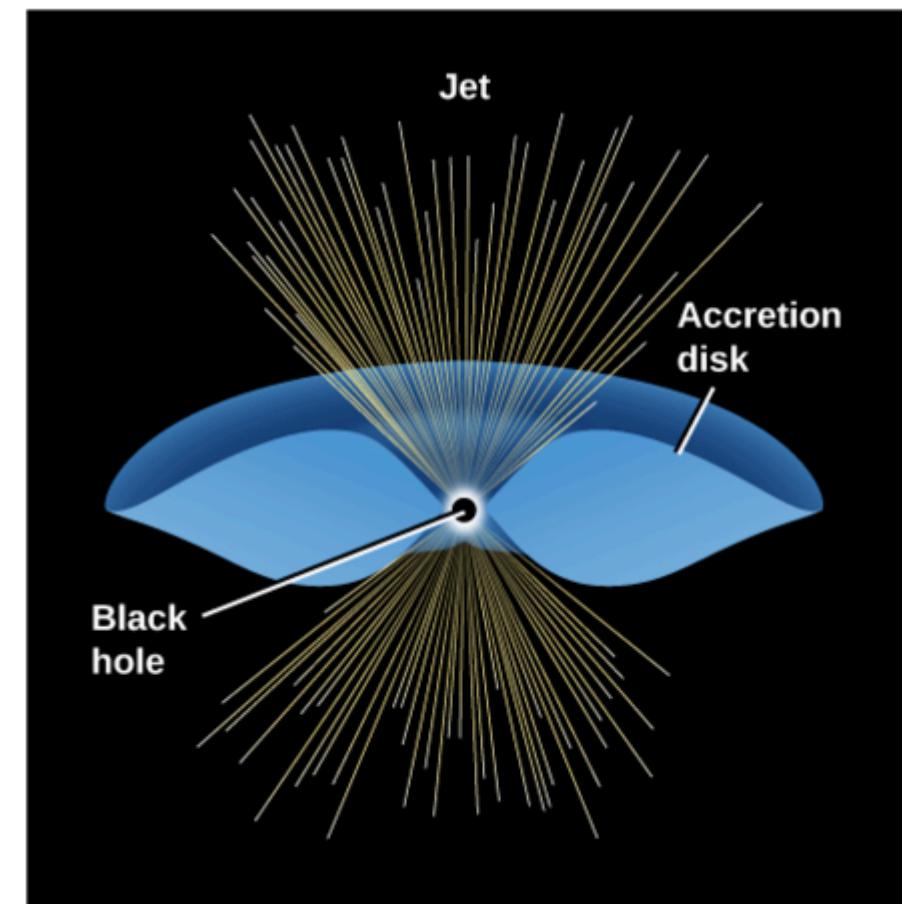
VLA radio

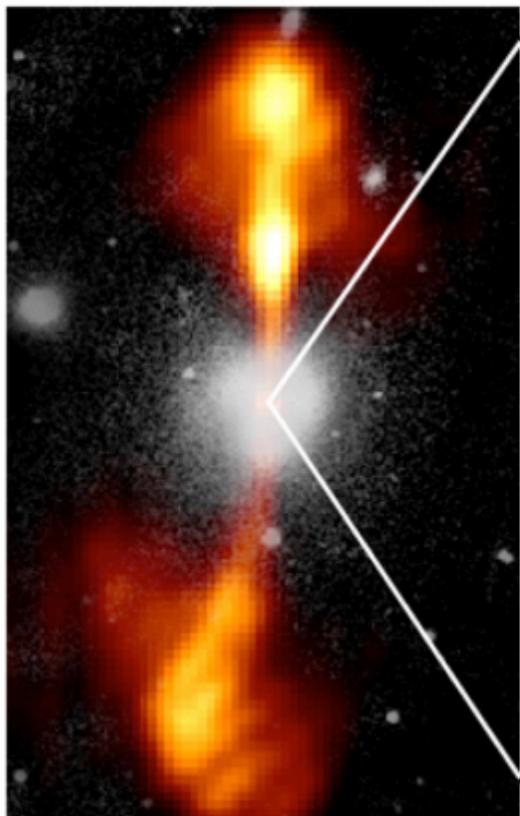


HST visible light

# Mass of black hole from velocity shifts

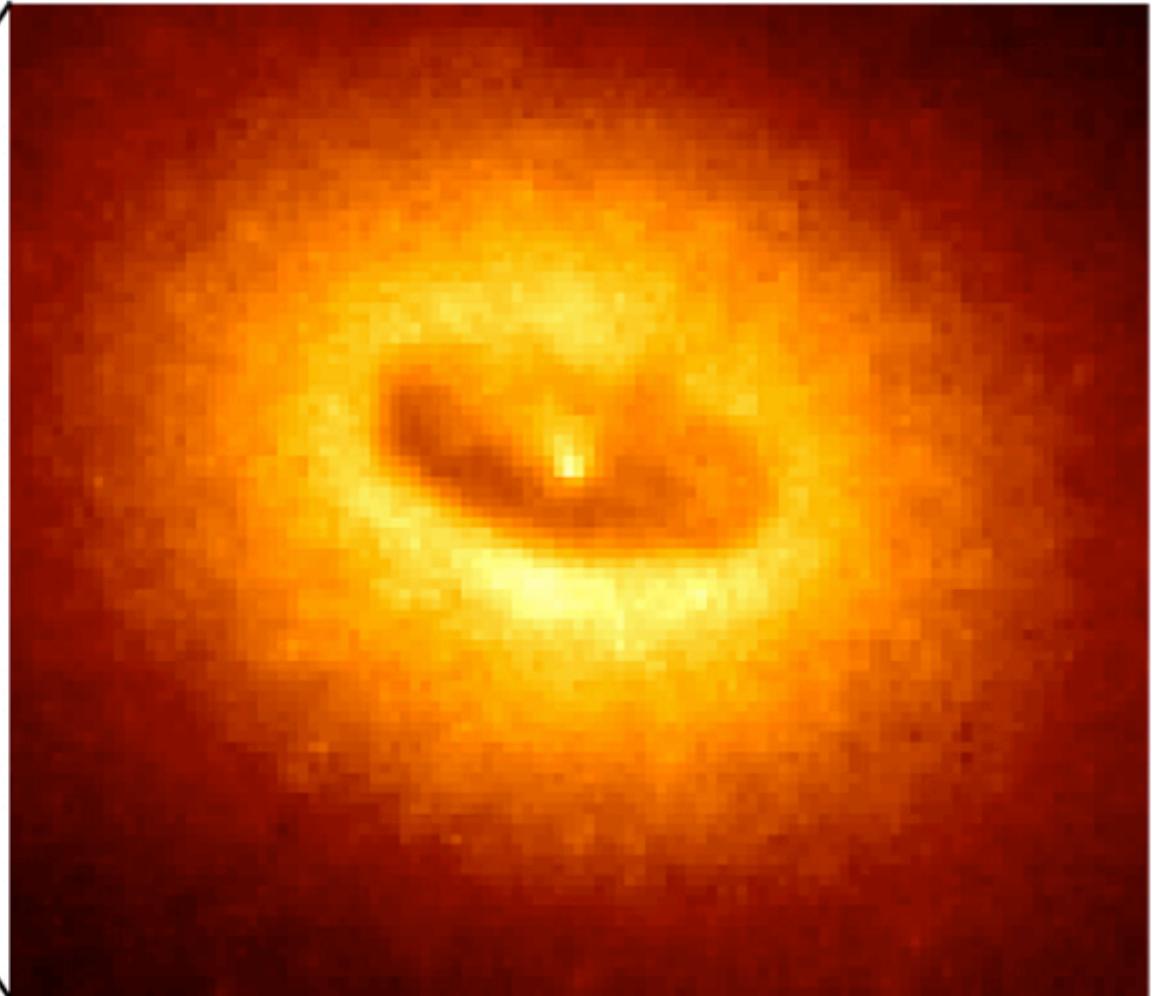






380 arc seconds

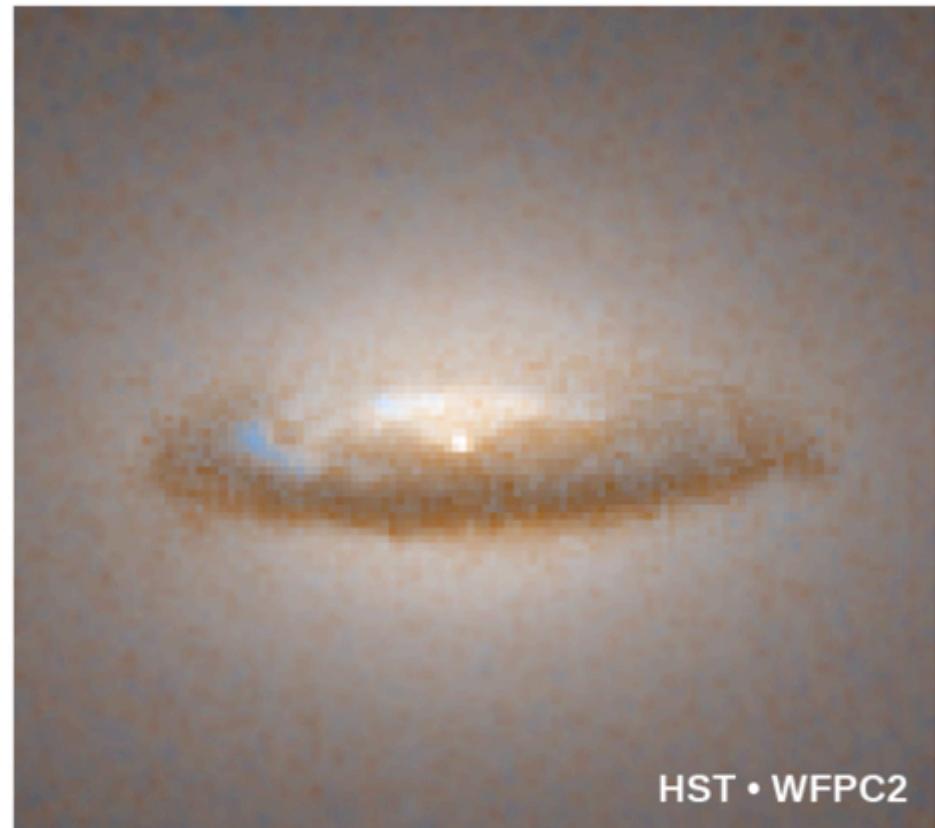
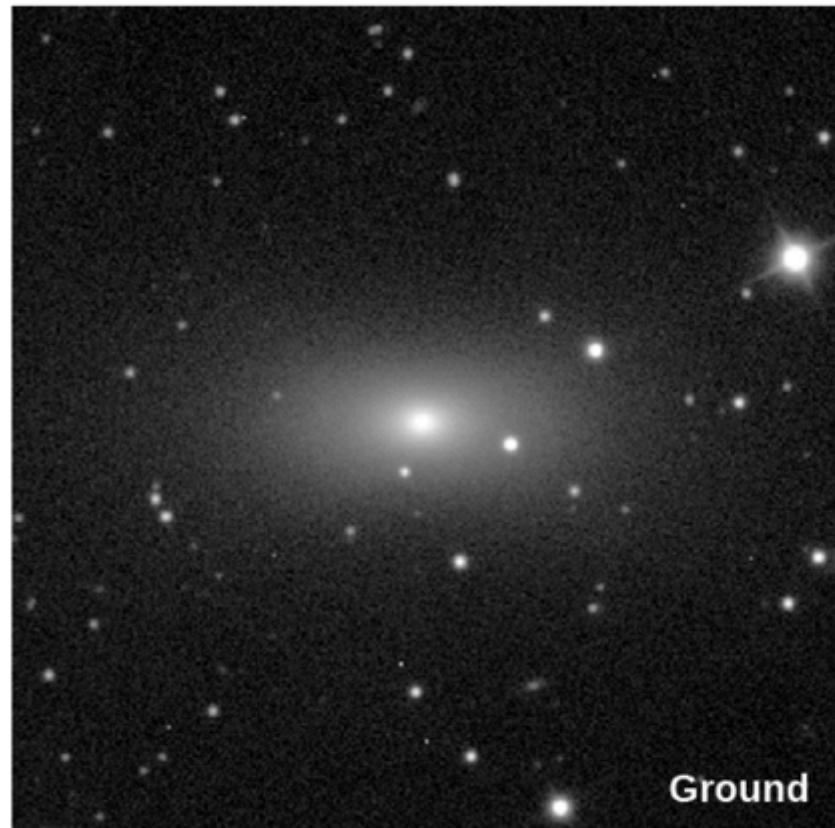
88,000 LY



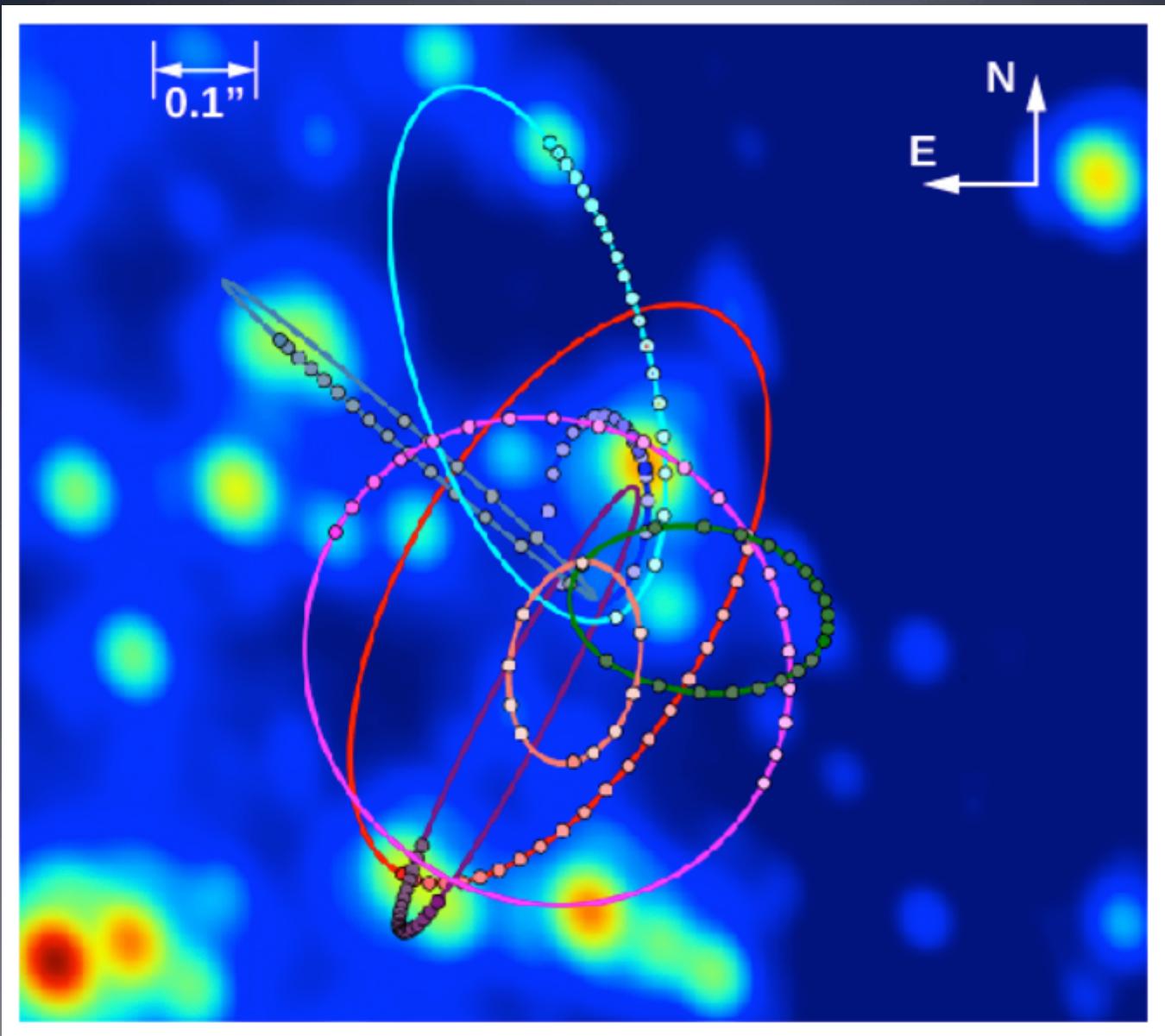
17 arc seconds

400 LY

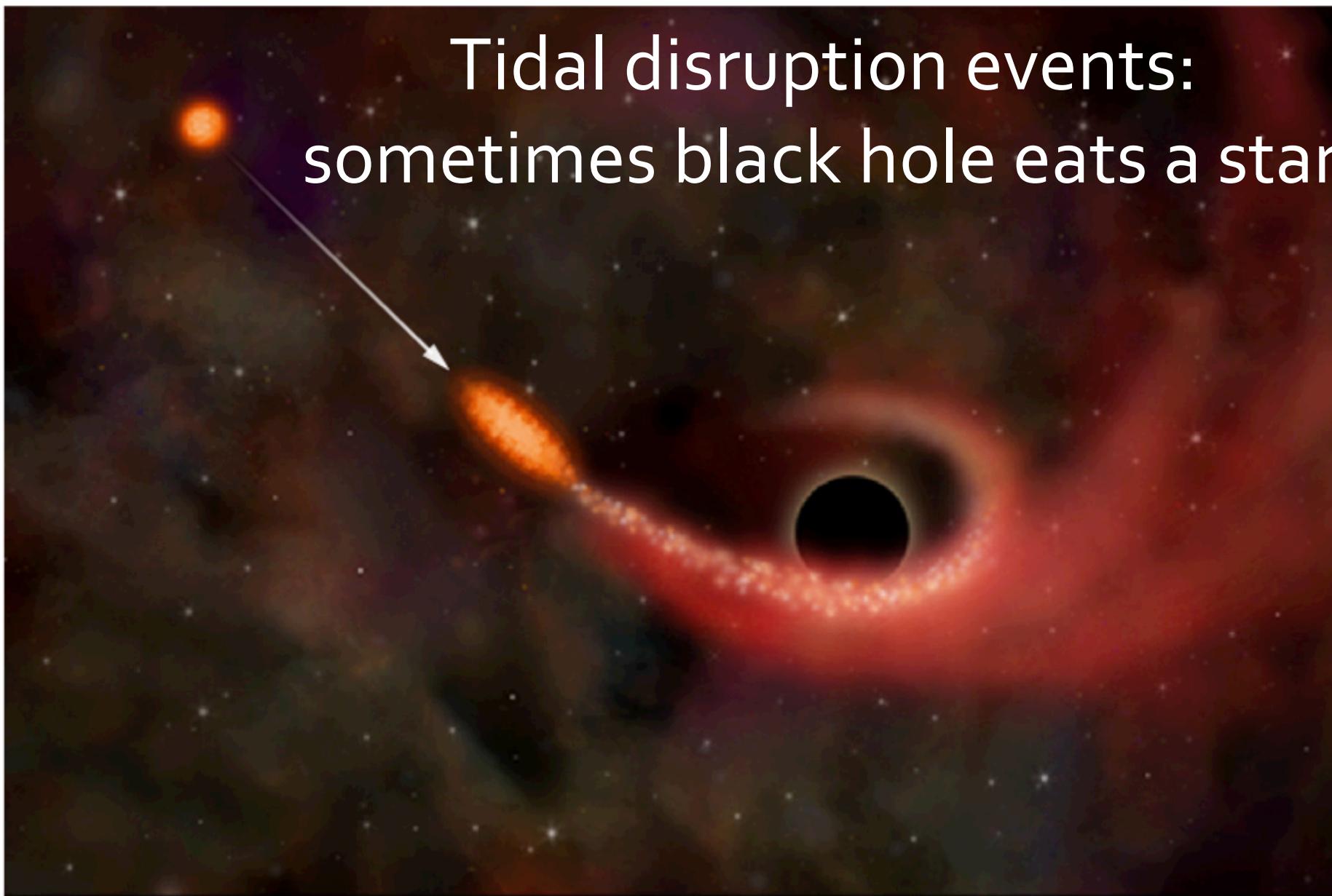
Imaging: can't get close enough to resolve  
the black hole  
(but exciting result next week)



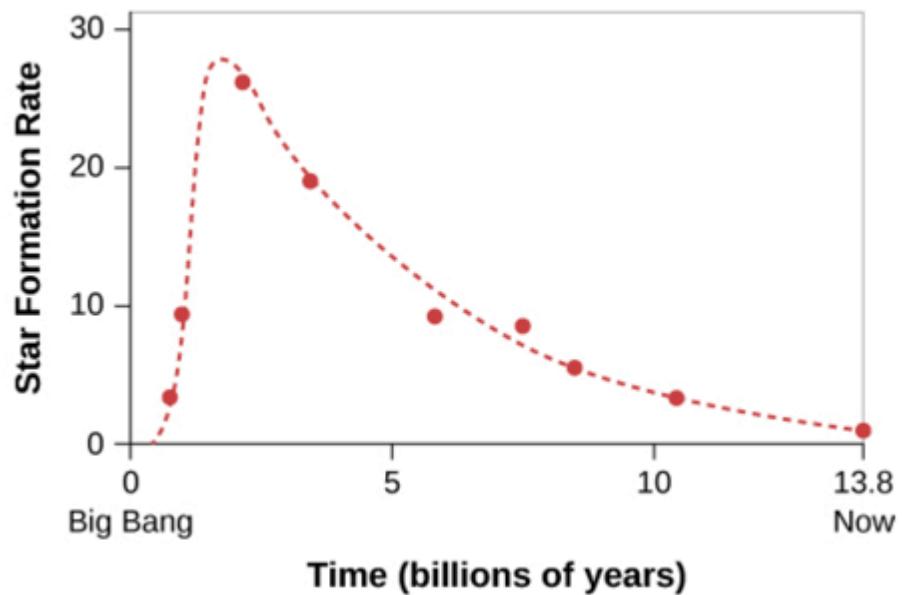
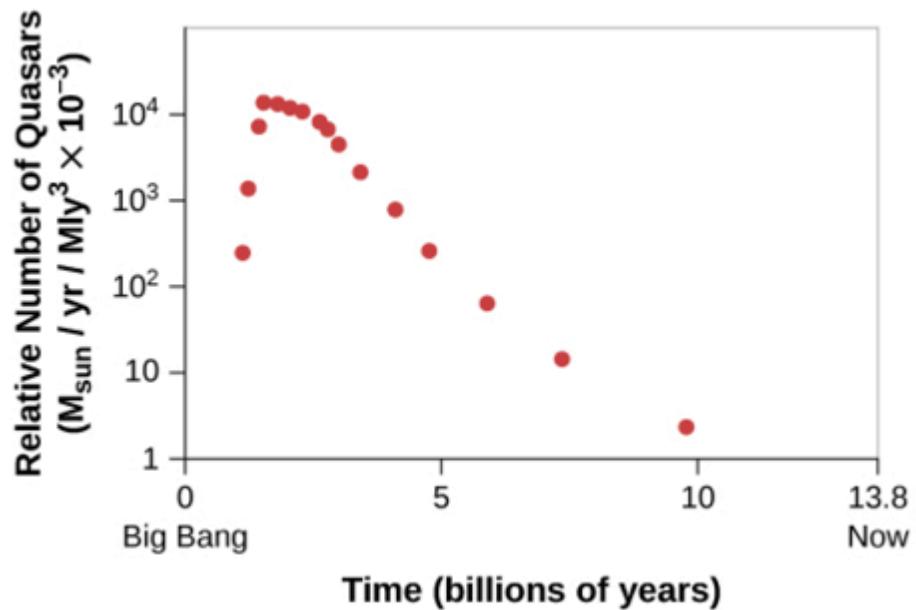
# Galactic center orbits



Tidal disruption events:  
sometimes black hole eats a star



# More quasars early in the universe



# Quasars and galaxies grow together

