

Active Galaxies

- Colliding galaxies and mergers
- Active galaxies
- Super-massive black holes

Colliding Galaxies

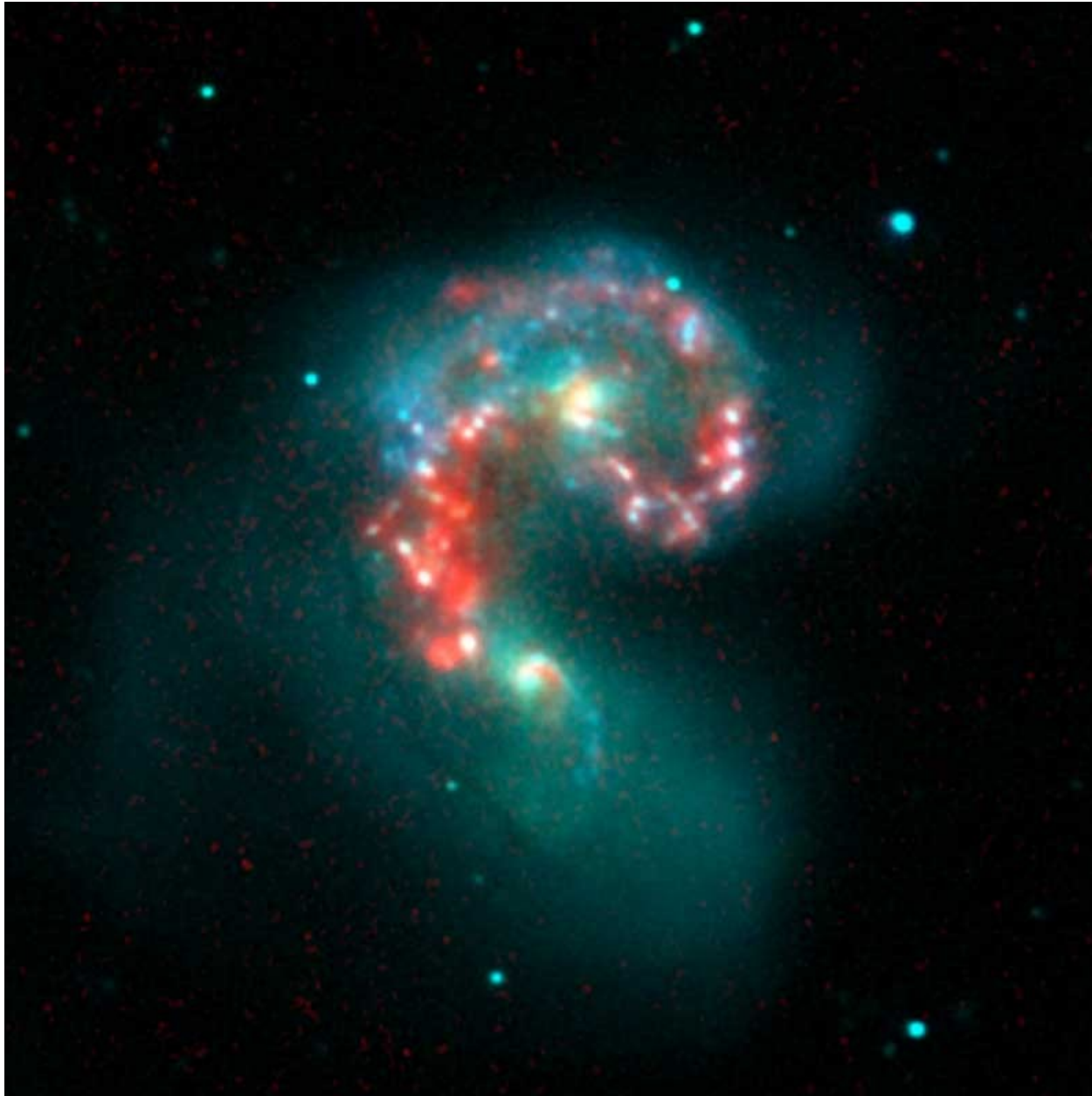
- When two large galaxies collide they get completely disrupted
- Large tidal tails can develop as the galaxies orbit each other in close proximity
- If both galaxies contain gas then this gets shocked and compressed
- This results in a burst of star formation – can result in a so-called starburst



Antennae
galaxies

Optical

Credit: NASA, ESA, and the Hubble Heritage Team (STScI/AURA)-ESA/Hubble Collaboration



Antennae

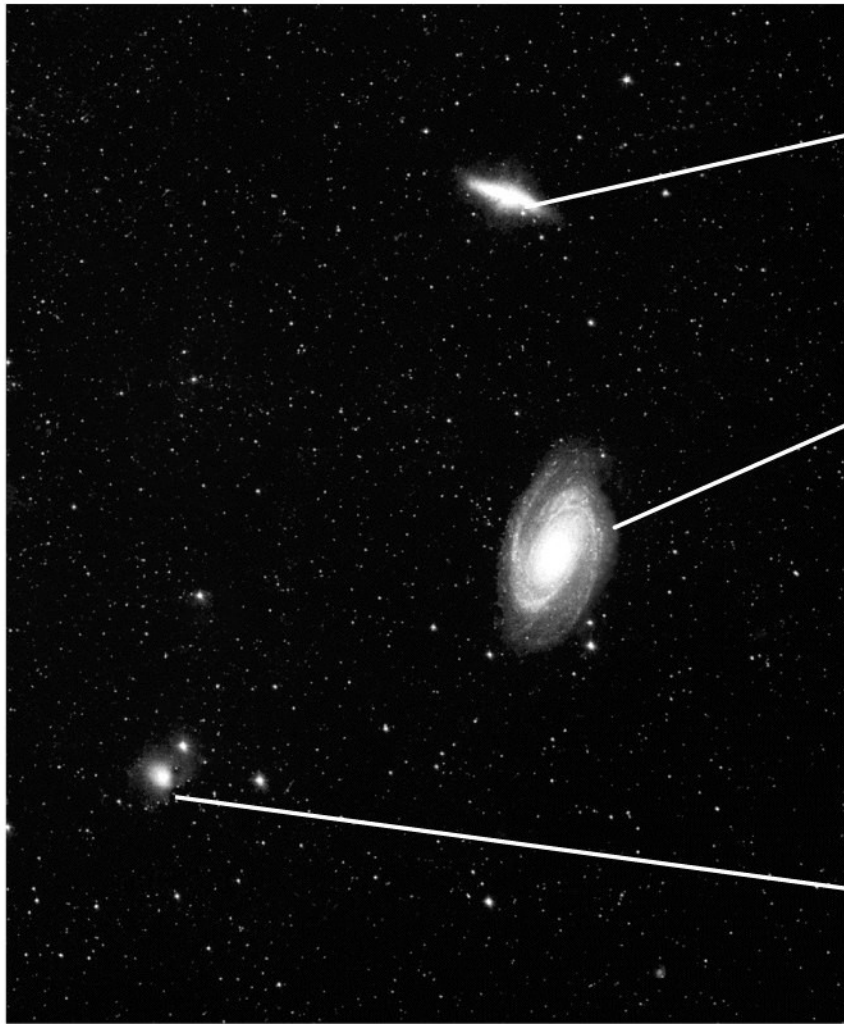
Mid-infrared

Credit: NASA/JPL-Caltech/Z. Wang (Harvard-Smithsonian CfA); Visible: M. Rushing/NOAO



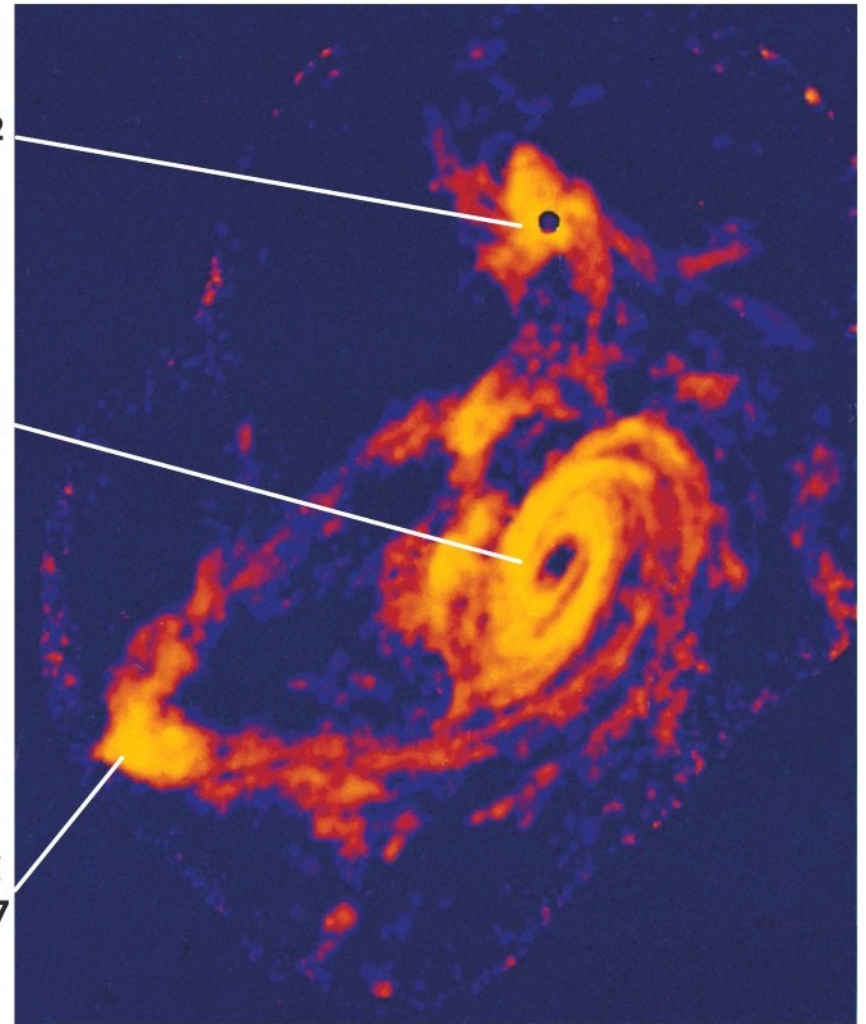
The
Tadpole
Galaxy

Credit: NASA, H. Ford (JHU), G. Illingworth (UCSC/LO), M.Clampin (STScI), G. Hartig (STScI), the ACS Science Team, and ESA



(a)

Optical: no obvious signs of interaction



(b)

H I: Tidal tails of atomic gas connecting the galaxies

Superwinds

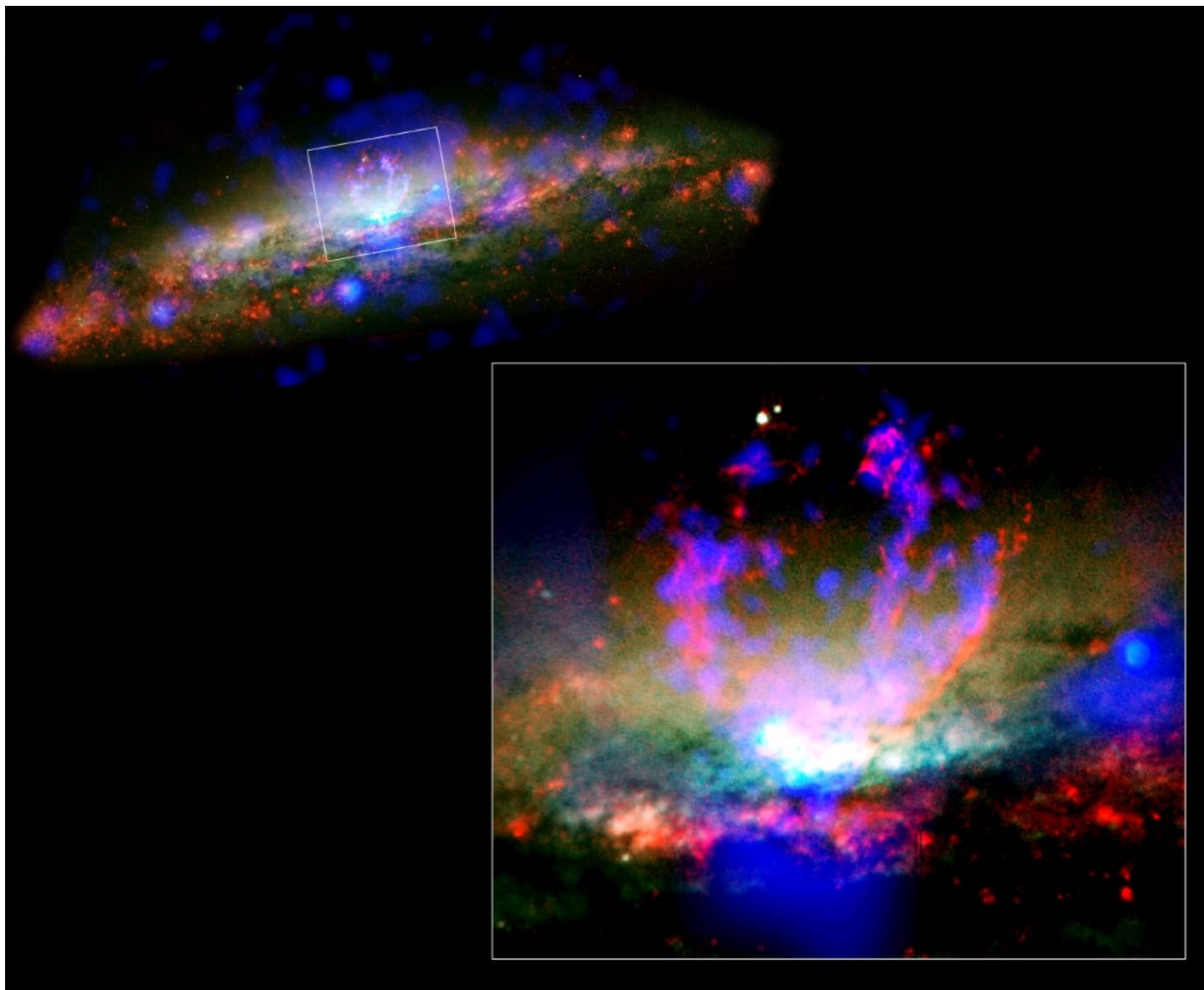
- The large numbers of massive stars and their supernovae in starbursts blows gas out of the galaxy
- This action can remove all gas from a galaxy, stopping all subsequent star formation, leading to the formation of an elliptical galaxy



M82 Optical: yellow/green, H α : red (HST)

X-ray: blue (Chandra)

Credit: X-ray: NASA/CXC/JHU/D.Strickland; Optical:
NASA/ESA/STScI/AURA/The Hubble Heritage Team; IR:
NASA/JPL-Caltech/Univ. of AZ/C. Engelbracht



NGC 3079

Optical:
red, green
(HST)

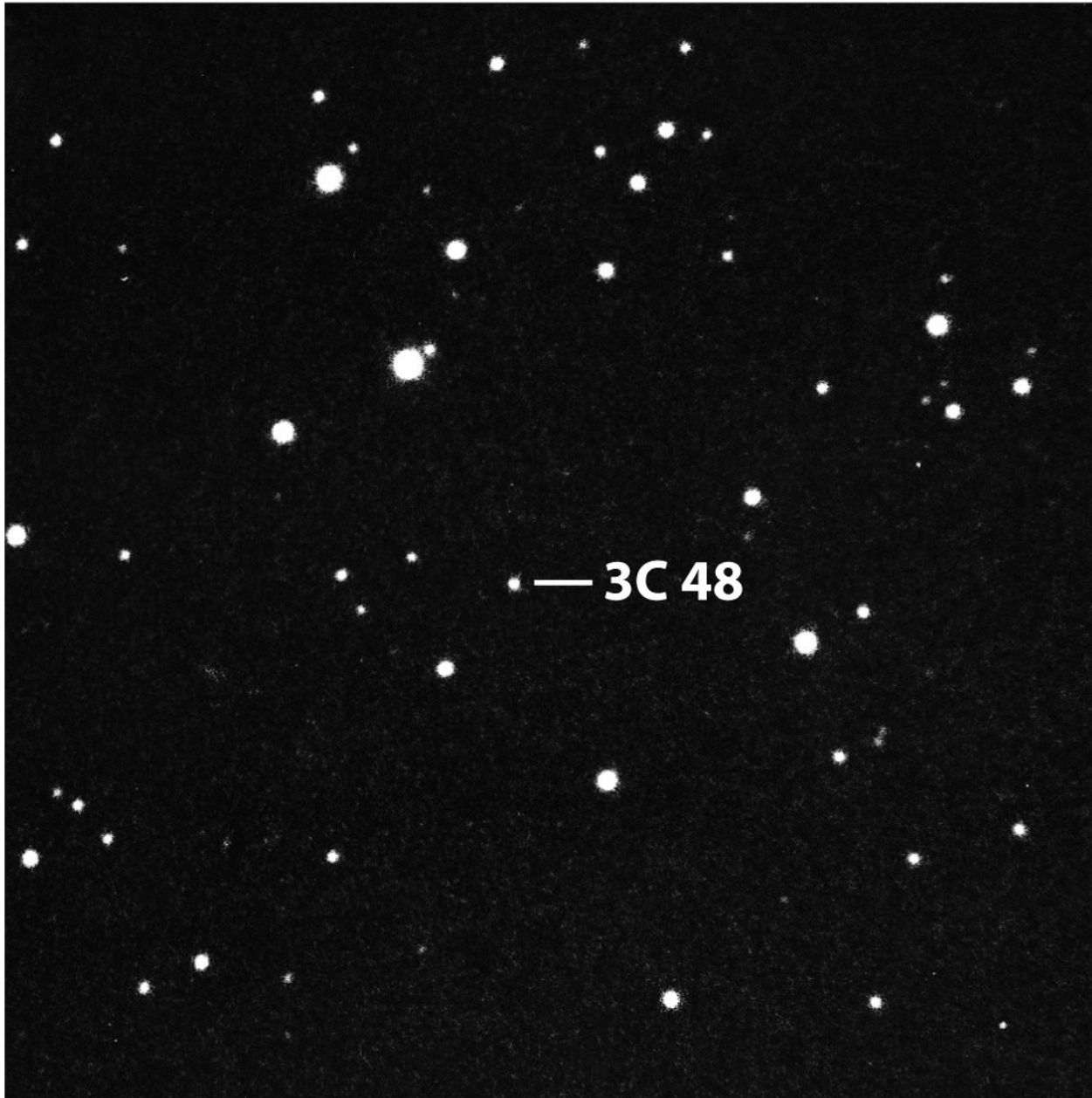
X-ray: blue
(Chandra)

Active Galaxies

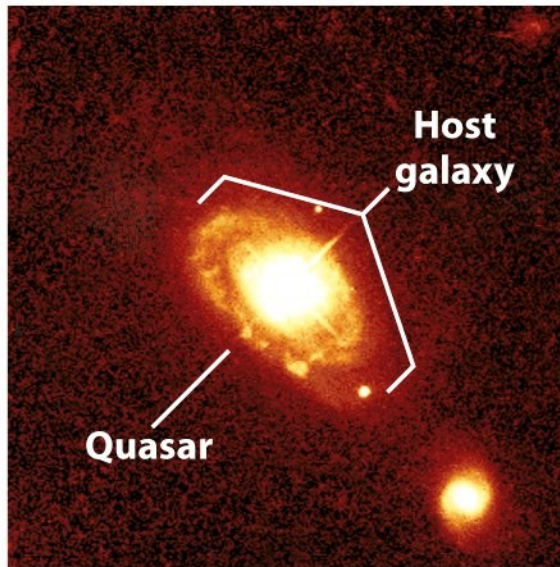
- Active galaxies have a luminous point-like nucleus (hence AGN)
- Spirals with a bright nucleus are called Seyfert galaxies
- Very luminous nuclei dominate the galaxy – quasi-stellar objects or quasars
- The high redshift quasar host galaxies show signs of interaction



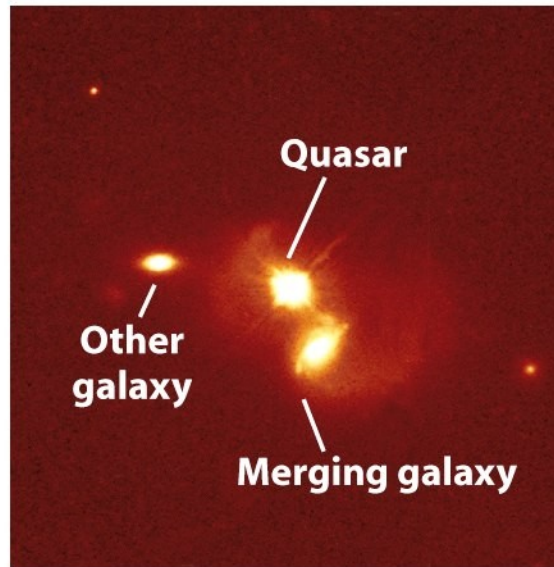
Active Galaxy (Seyfert) NGC 4051 Image Credit: George Seitz/Adam Block/NOAO/AURA/NSF



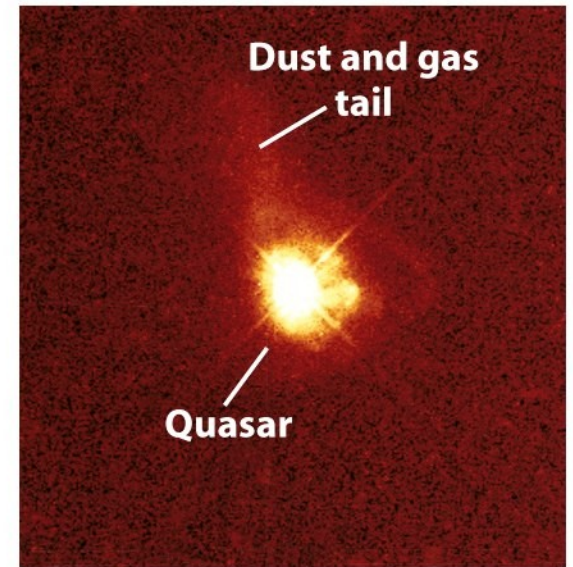
Optical image
of quasar



(a)



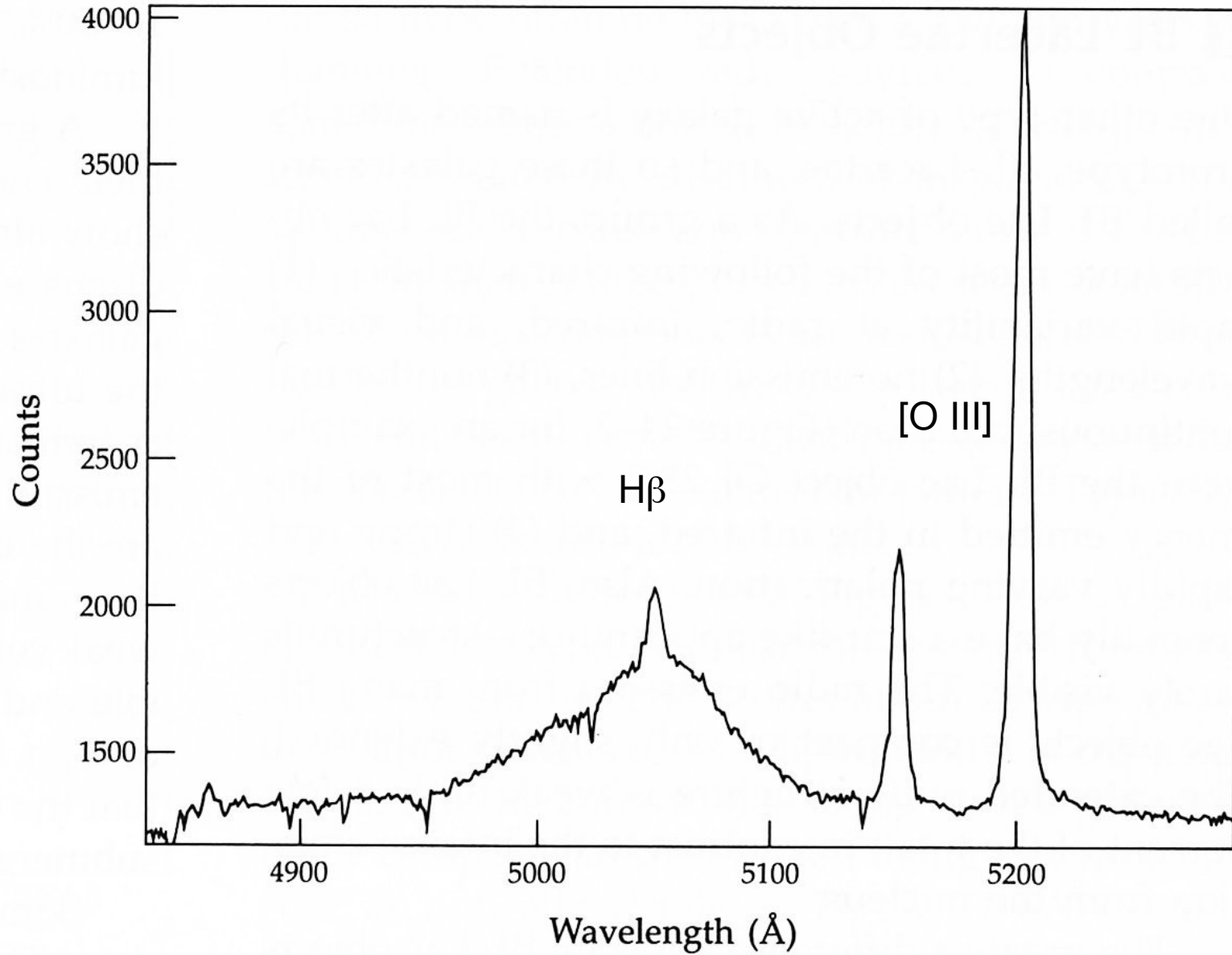
(b)



(c)

- HST has revealed the host galaxies of some quasars
- Most show signs of interaction

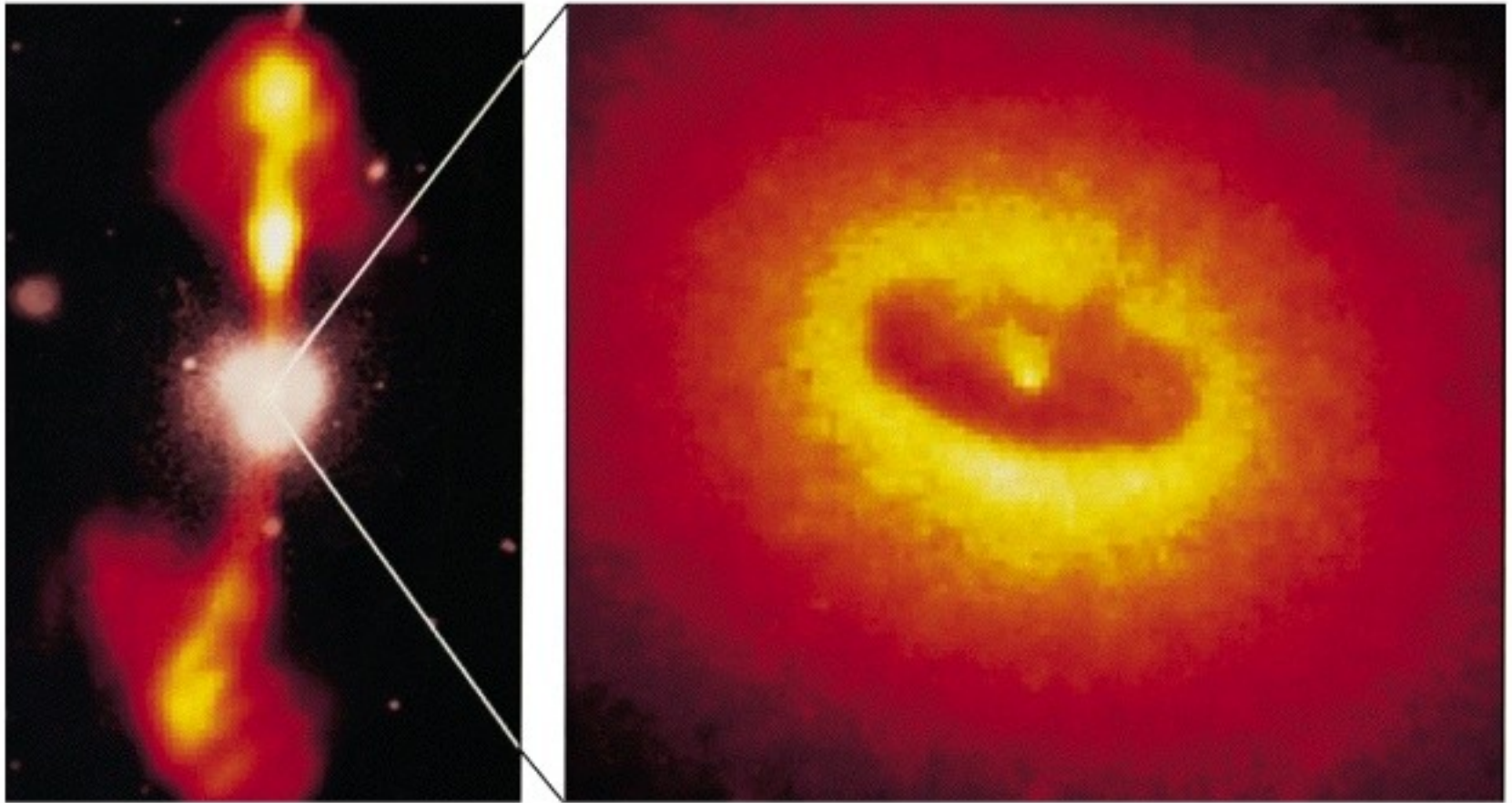
- The nucleus has a non-thermal continuum spectrum that extends from radio to X-rays
- Also has an emission line spectrum where the Balmer lines are often seen to be very broad



Active galaxy optical spectrum showing broad emission line (Zeilik Fig 24-2)

Accretion Discs

- The broad lines seen in AGN spectra can be explained by rotation of material around the super-massive black hole in a rotating accretion disc – also called the broad line region
- Rotating, magnetic disc drives a jet
- Hot gas in evacuated cavities gives rise to the narrow emission lines – called narrow line region



a

b

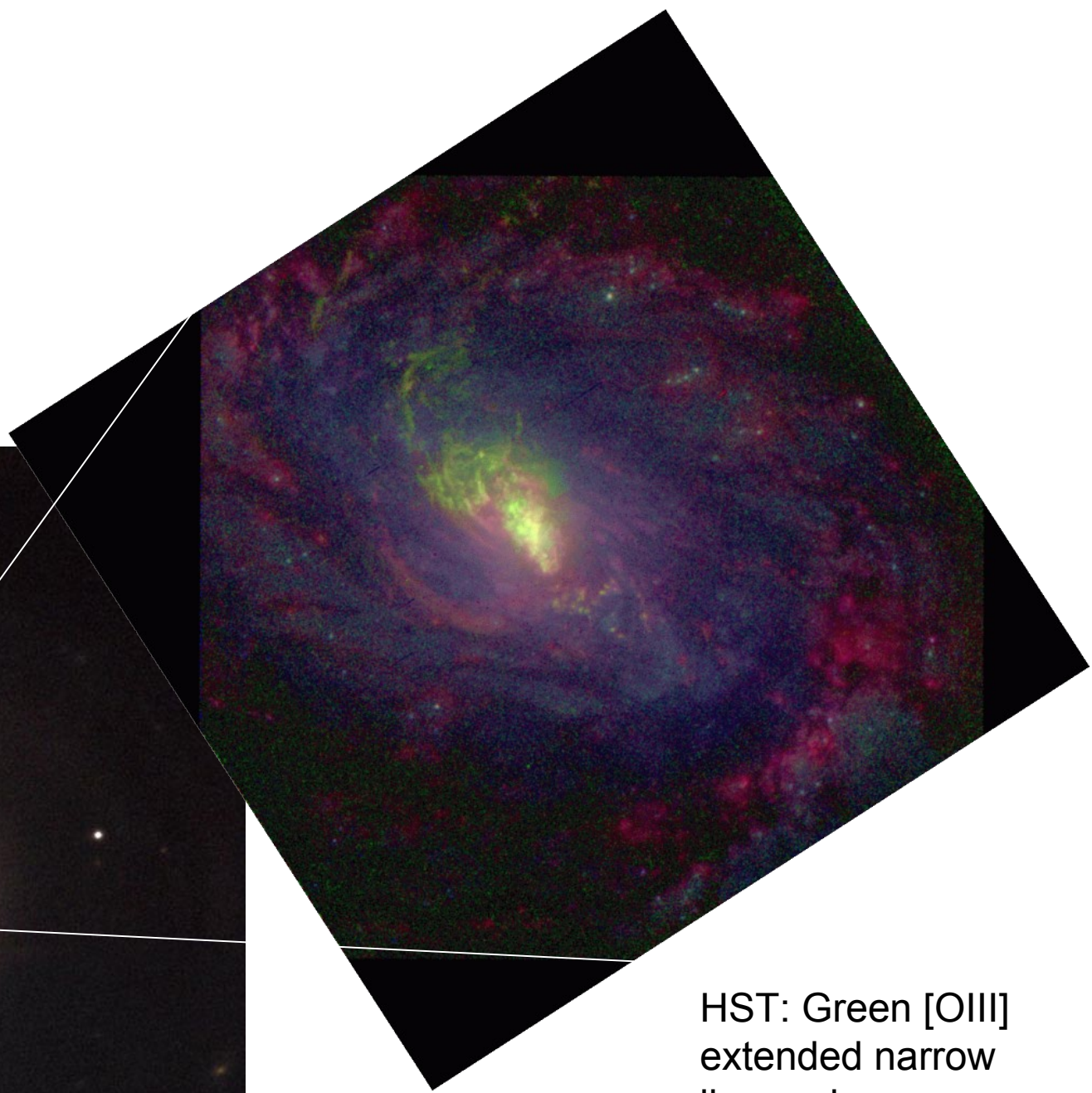
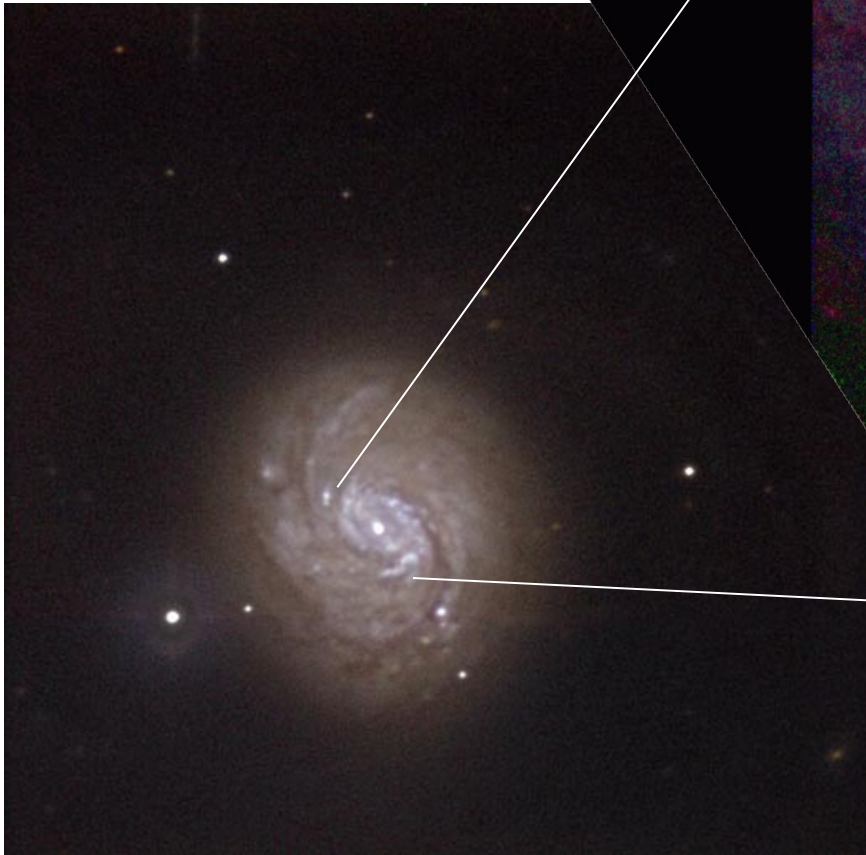
NGC 4261 Radio and
Optical

NGC 4261 HST image of
disc around the nucleus

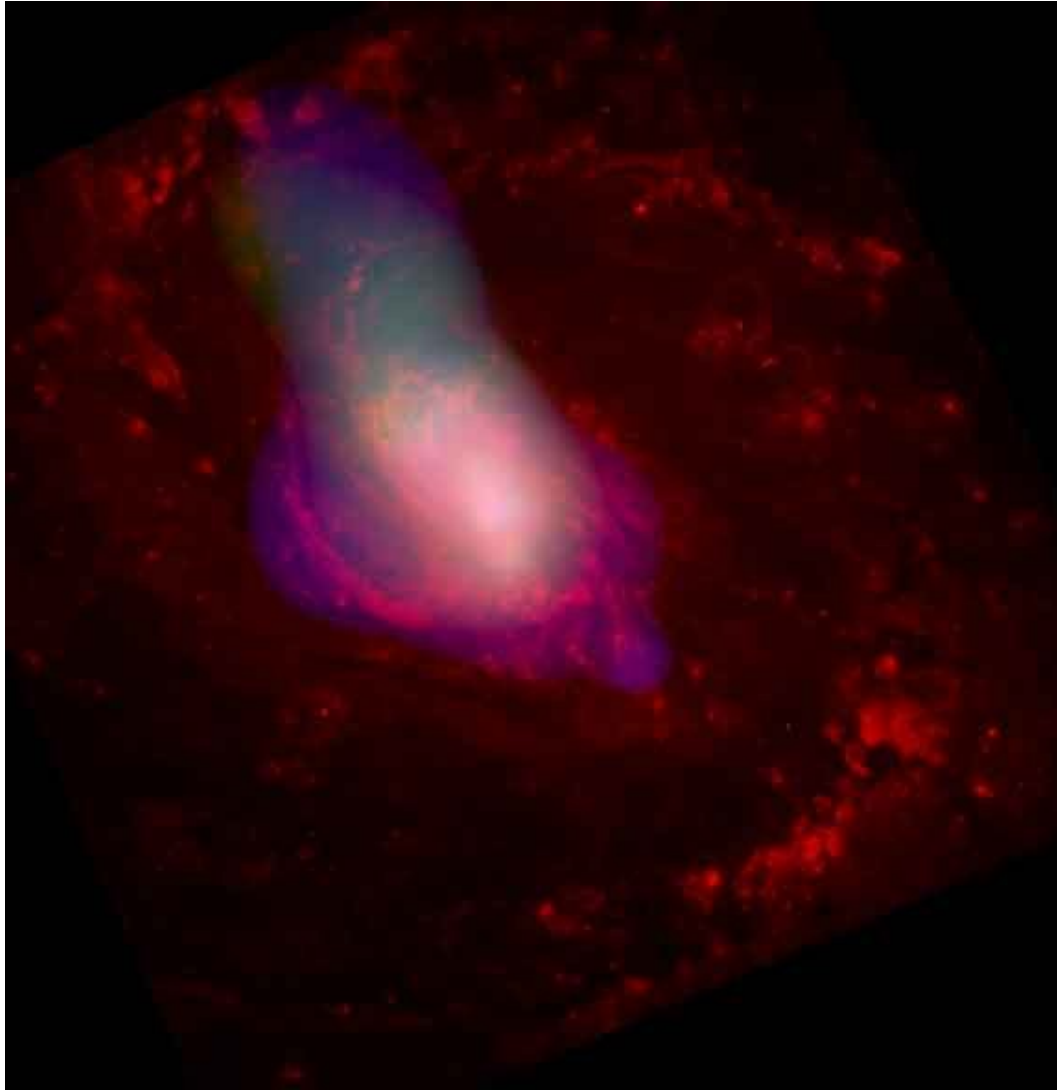
Credit: National Radio Astronomy Observatory, California Institute of Technology
Credit: Walter Jaffe/Leiden Observatory, Holland Ford/JHU/[STScI](#), and [NASA](#)

NGC 1068

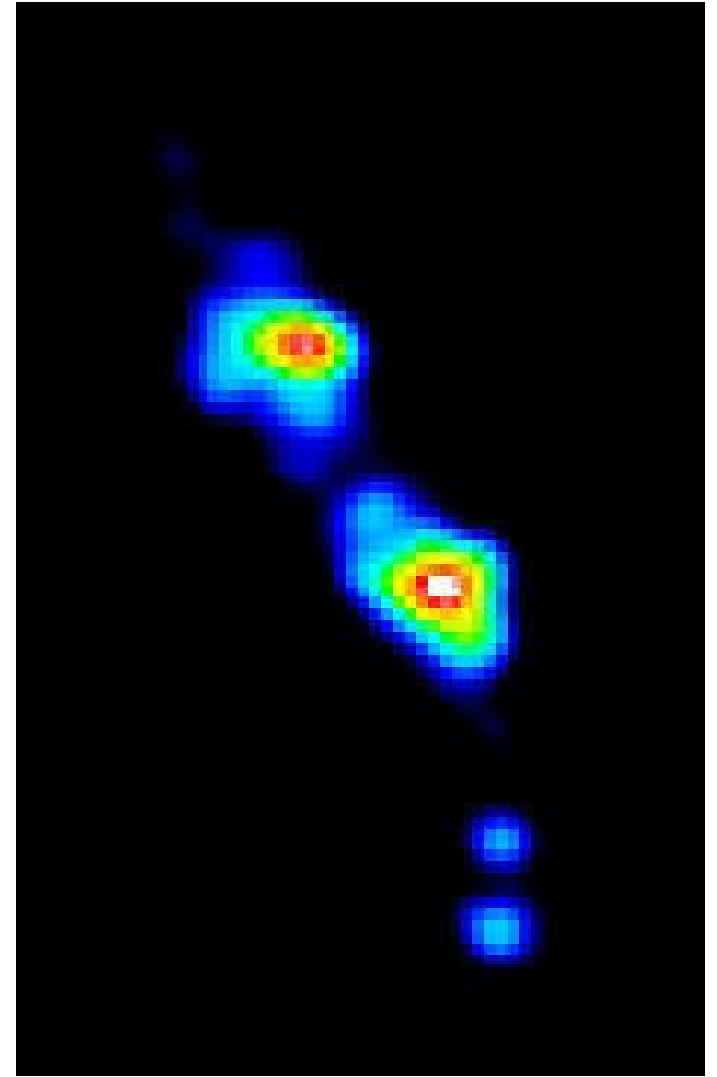
Seyfert 2



HST: Green [O III]
extended narrow
line region



Chandra X-ray (green & blue) HST (red) 2 arcmin



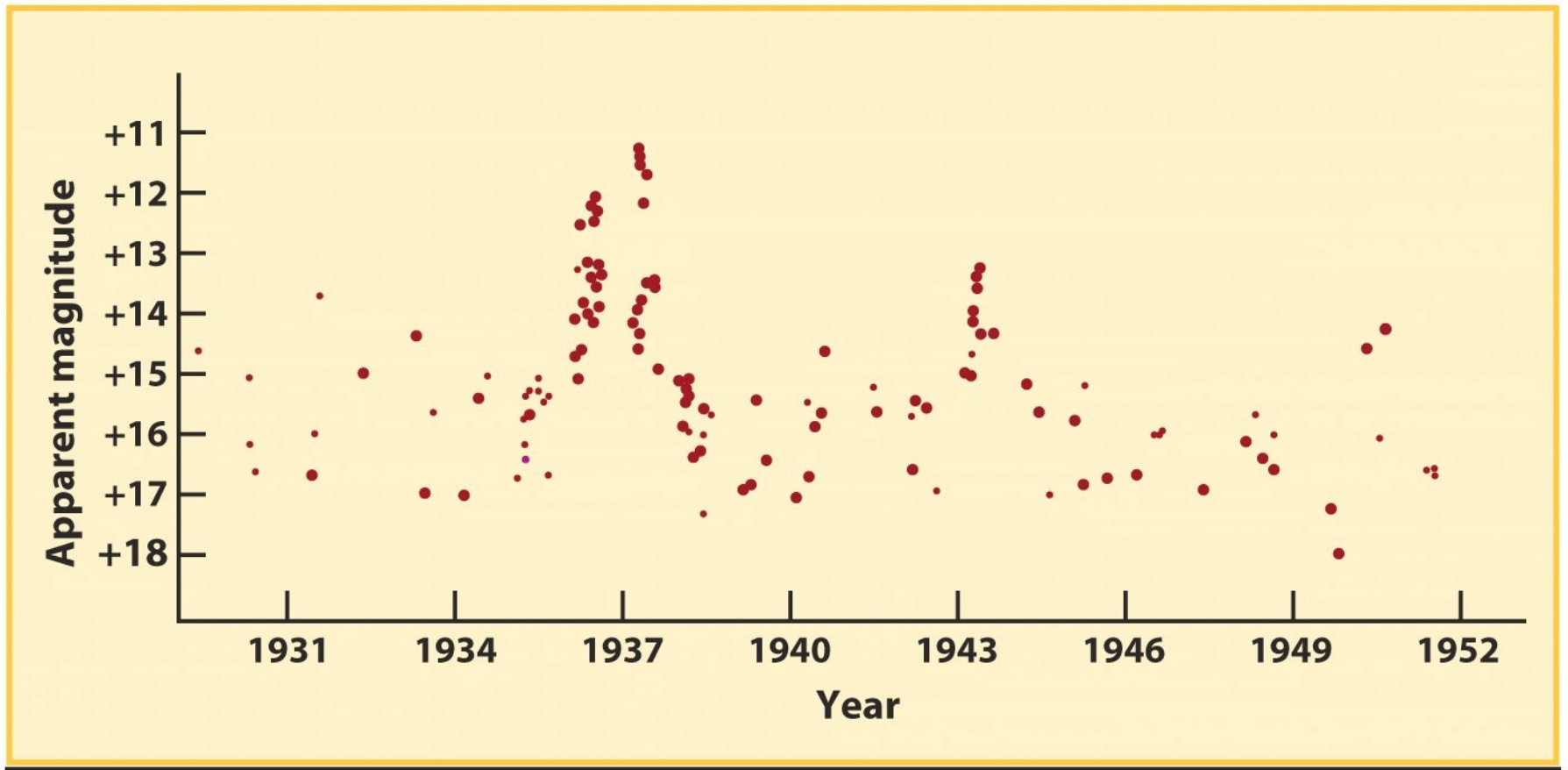
Radio: MERLIN 2 arcsec

Variability

- Most AGN show variability in their brightness on timescales of months
- The variability timescale allows an upper limit to be placed on the size of the emitting region

$$l \leq ct$$

where l is the size of the region and t is the variability timescale



Light curve showing the variability of the continuum for an AGN

Super-massive Black Holes

- The high luminosity from such a small region can only be explained by the release of gravitational potential energy of material falling onto a very massive, compact object – a super-massive black hole

AGN Luminosity

- The total amount of energy available from letting an amount of material with mass m , fall onto an object of mass M , size R is

$$E = \frac{GMm}{R}$$

- If material is falling at a rate

$$\dot{m} = \frac{dm}{dt}$$

- And some fraction ε is turned into radiation
the luminosity is

$$L = \varepsilon \frac{GM\dot{m}}{R}$$

- If material gets to the Schwarzschild
radius

$$L = \varepsilon \frac{1}{2} \dot{m} c^2$$

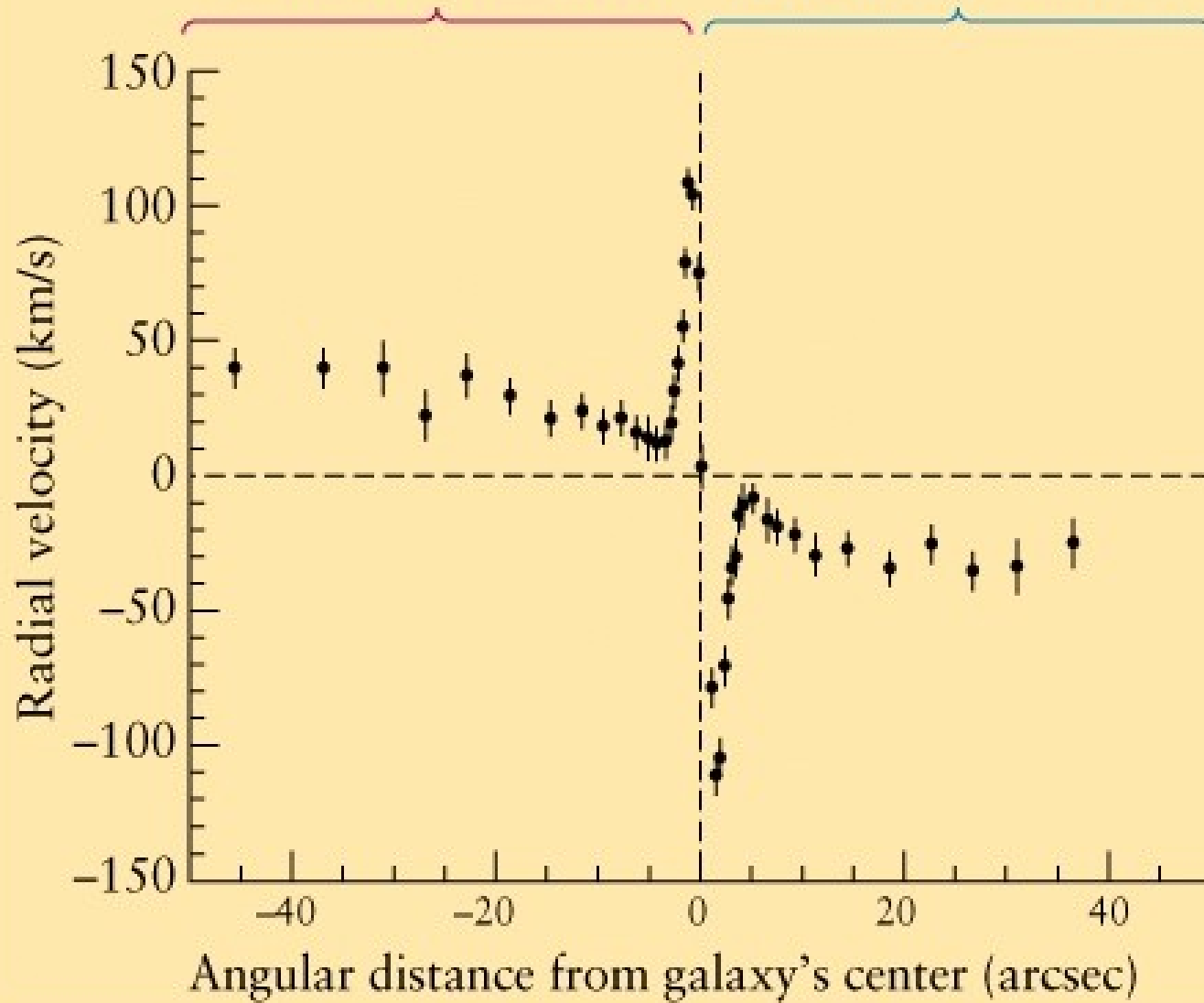
- The efficiency, ε , is thought to be about
10%

Black Hole Masses

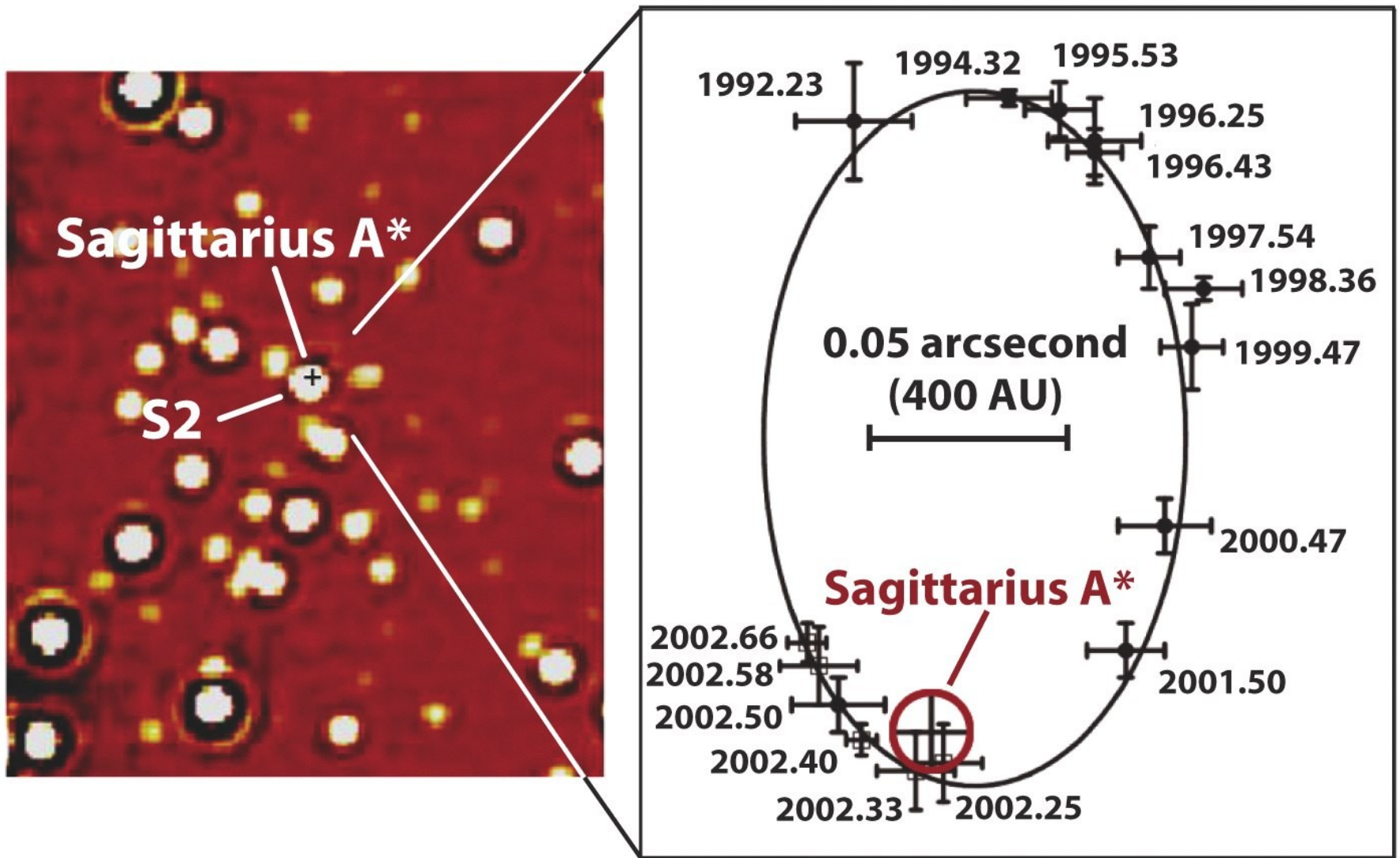
- Super-massive black holes are revealed by the fast motion of stars near the centres of nearby galaxies
- The Doppler effect used to measure the mass
- Millions to billions of solar masses
- All galaxies possess central black holes, not just active ones, even our own

This side of the galaxy
is receding from us
(its light is redshifted)

This side of the galaxy
is approaching us
(its light is blueshifted)



Stellar radial
velocities in
the core of
M31

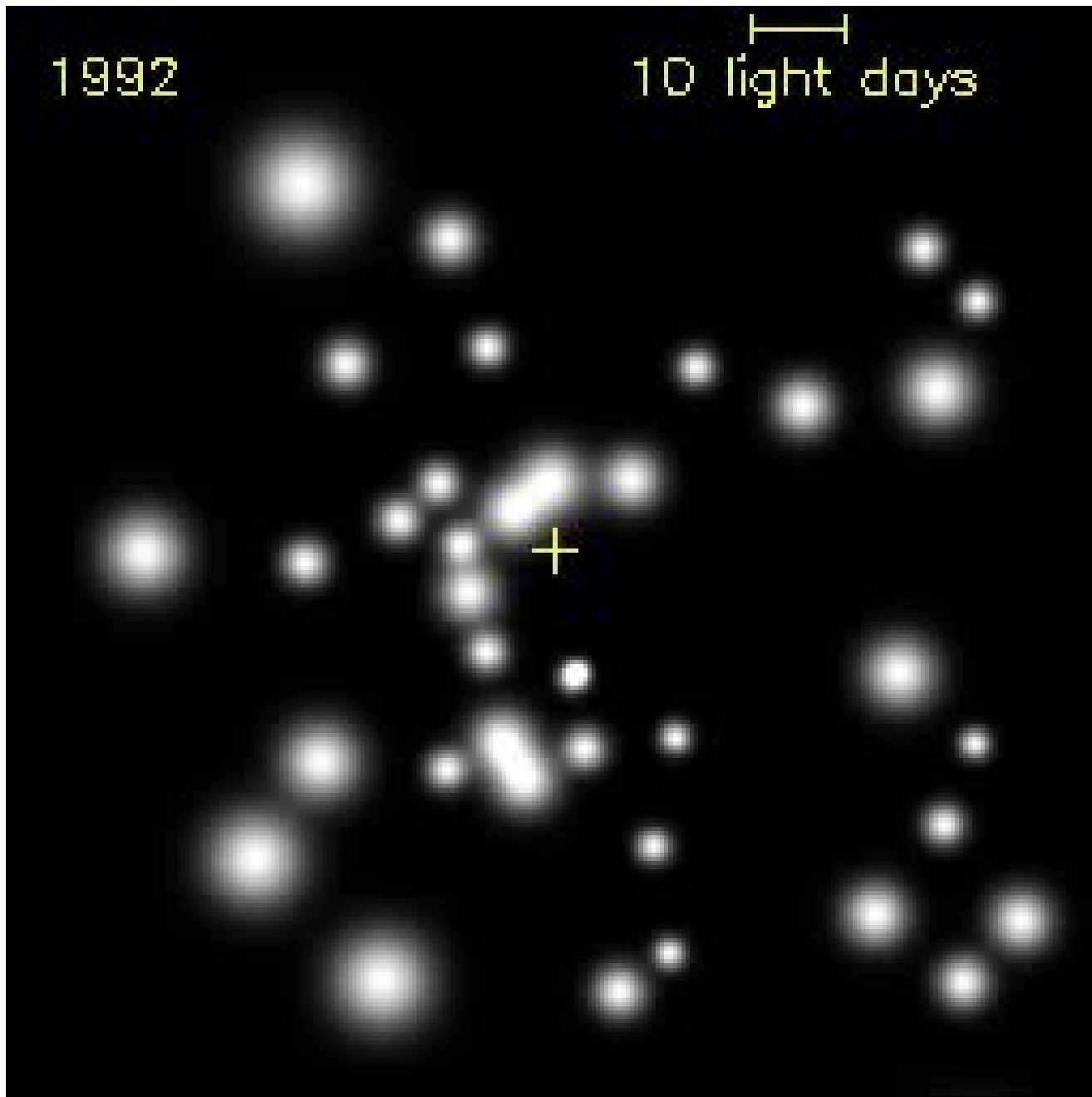


- Stellar orbits prove our Galaxy has a $4 \times 10^6 M_{\odot}$ black hole at the centre

Genzel MPE,
Garching

1992

10 light days



Summary

- Galaxy interactions and mergers can result in a starburst and superwind
- Could also fuel accretion on to supermassive black hole at centre resulting in AGN activity.
- One of the main causes of evolution in the galaxy population over time