Active Galaxies

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

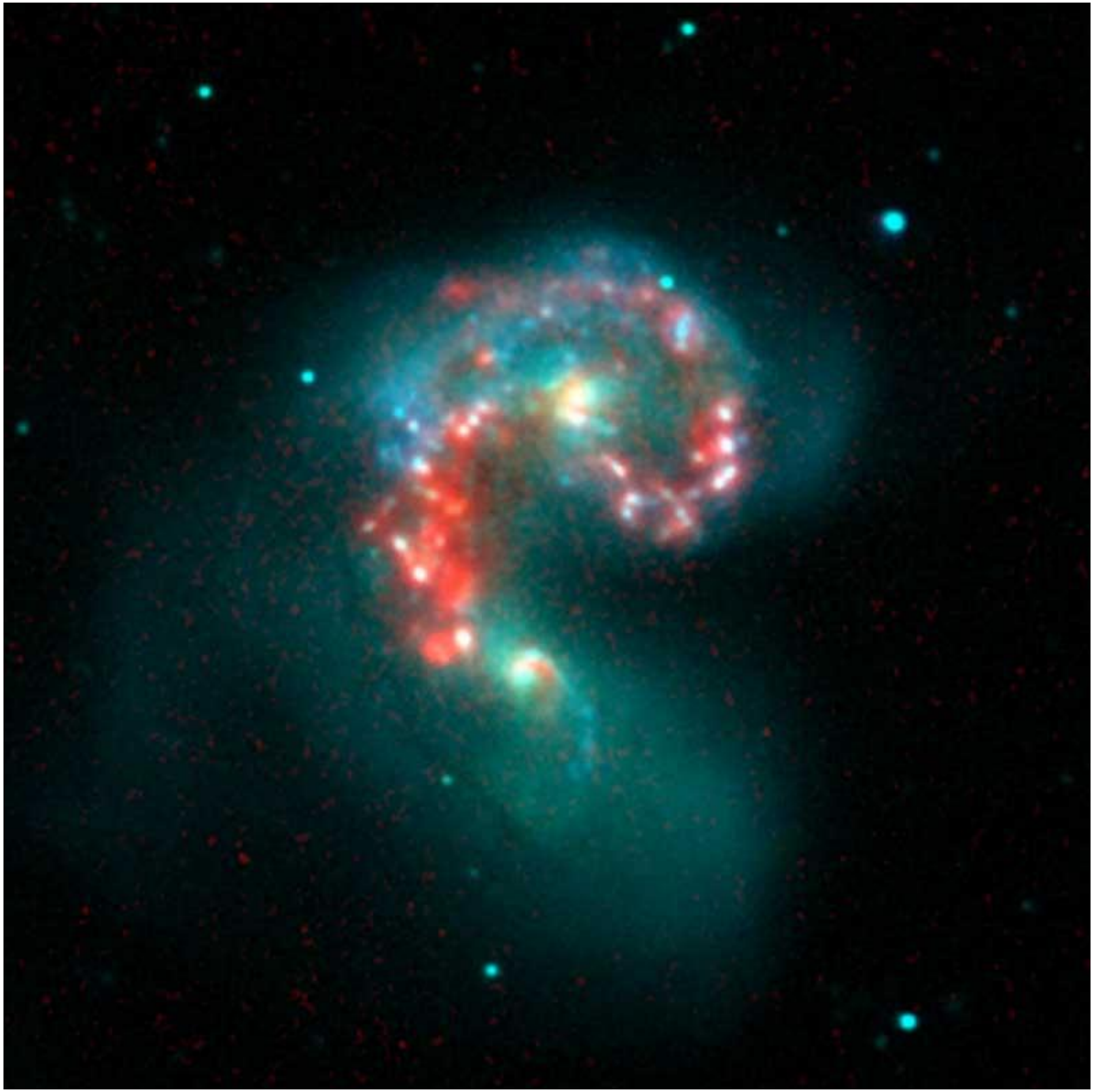
Colliding Galaxies

- 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



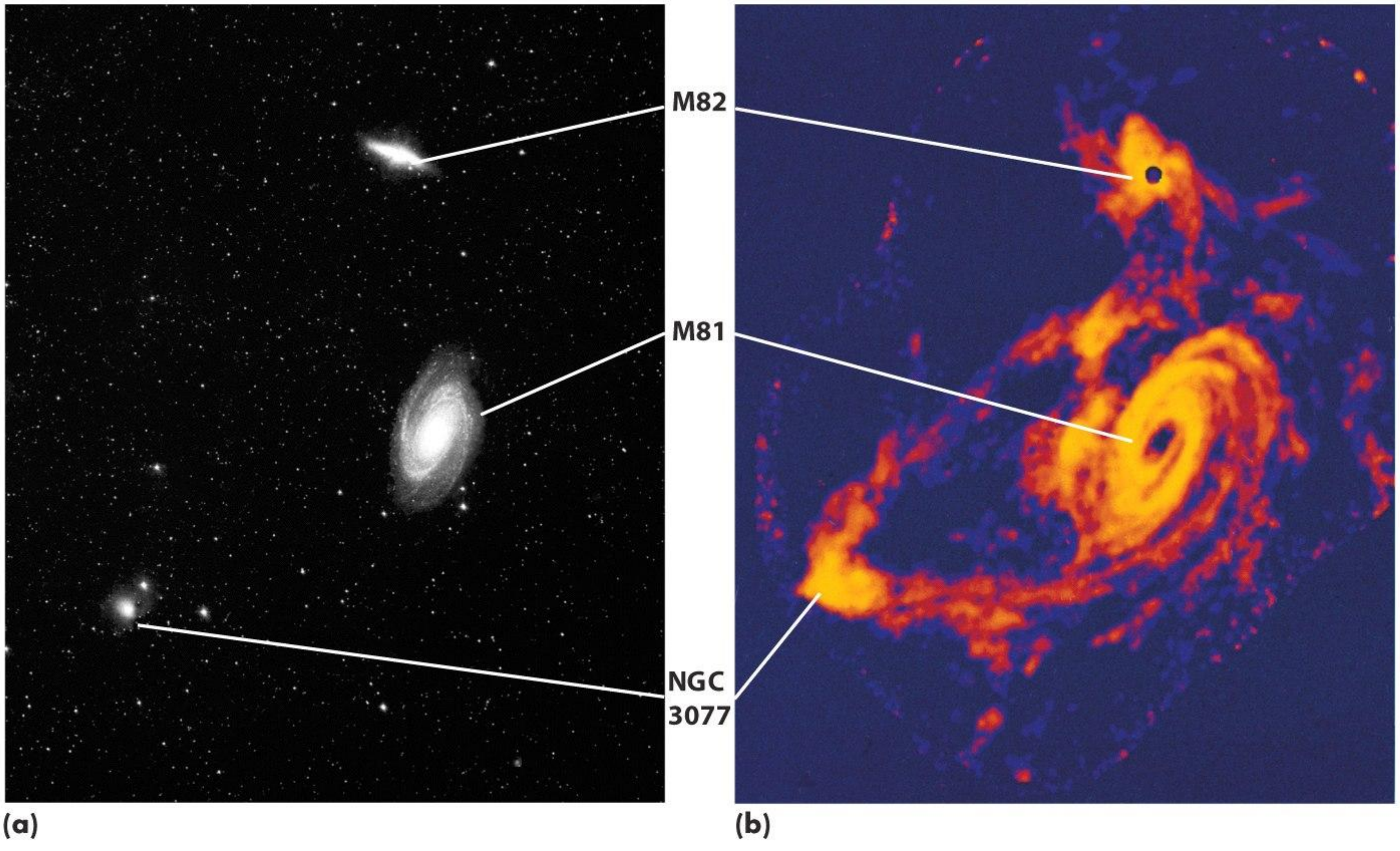
Antennae

Mid-infrared

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

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

The Tadpole Galaxy



Optical: no obvious signs of interaction

H I: Tidal tails of atomic gas connecting the galaxies

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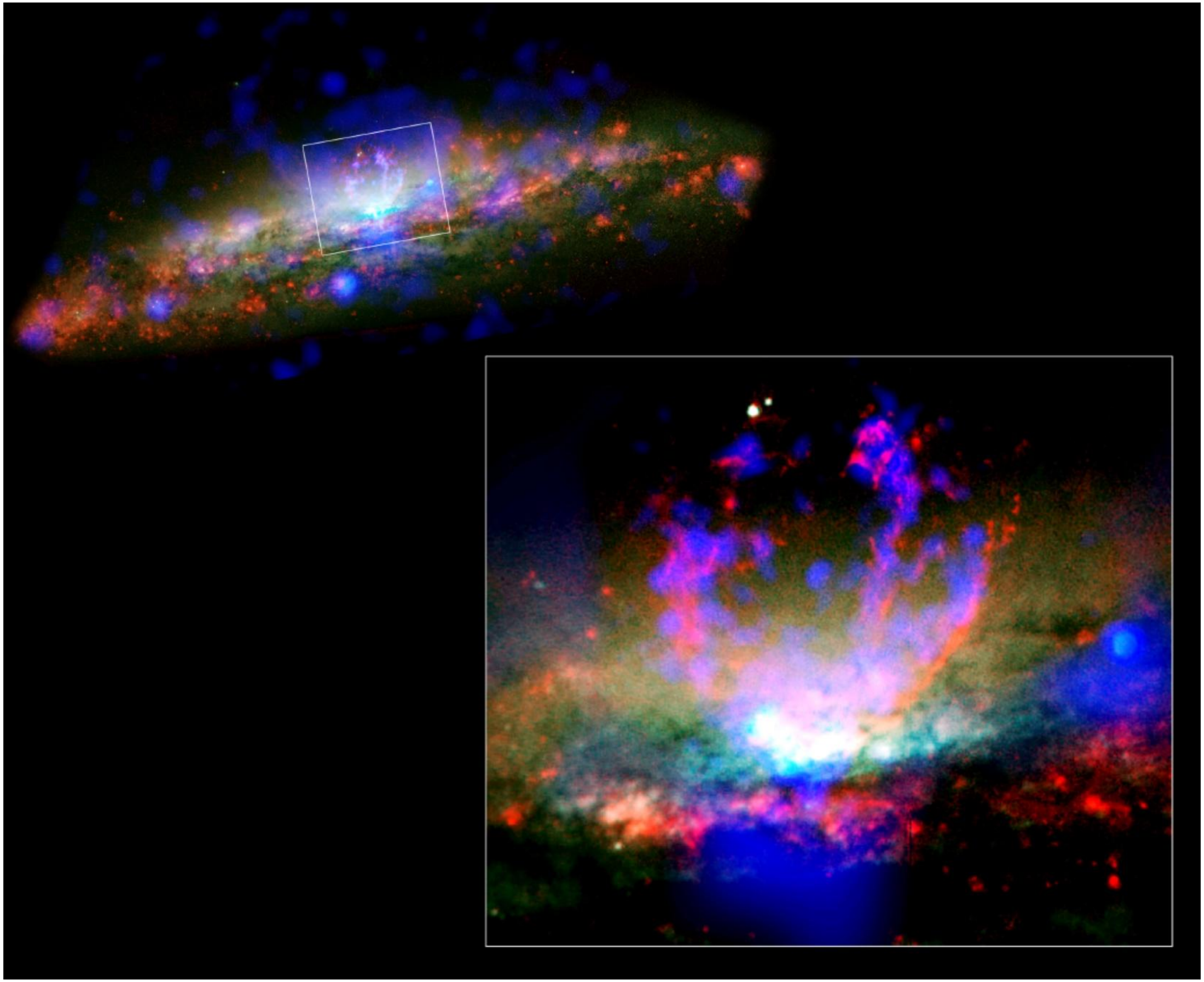
Superwinds

- 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, Hα: 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

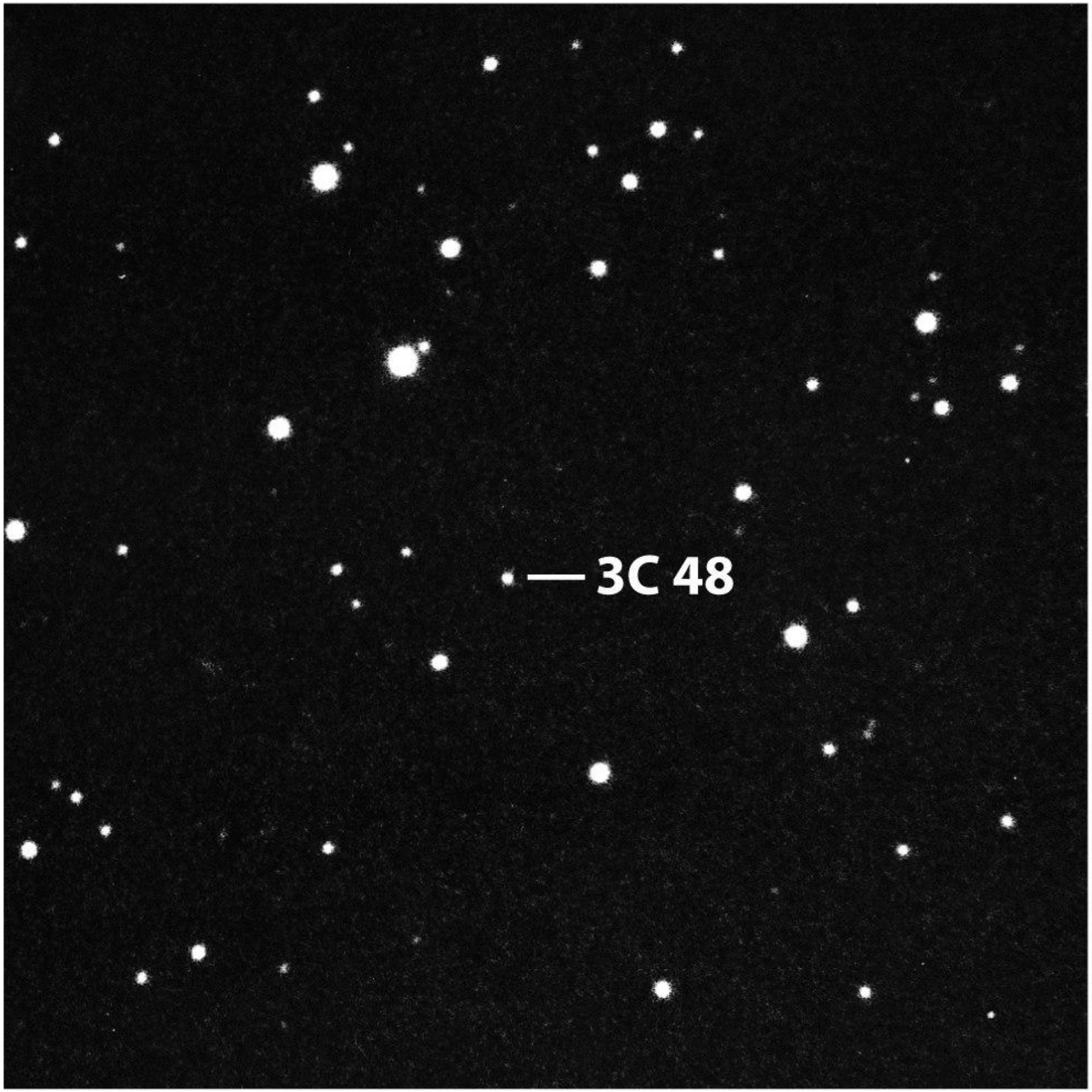
(Chandra)

Credit: NASA/CXC/STScI/U.North Carolina/G.Cecil

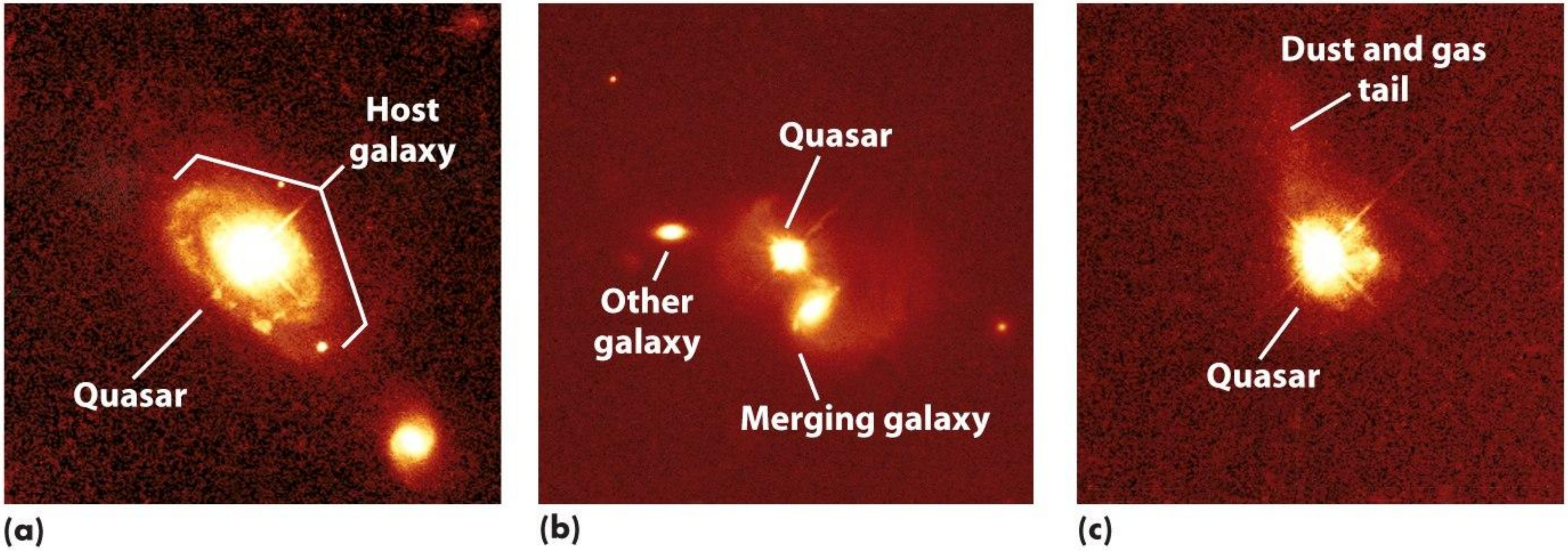
Active Galaxies

- 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

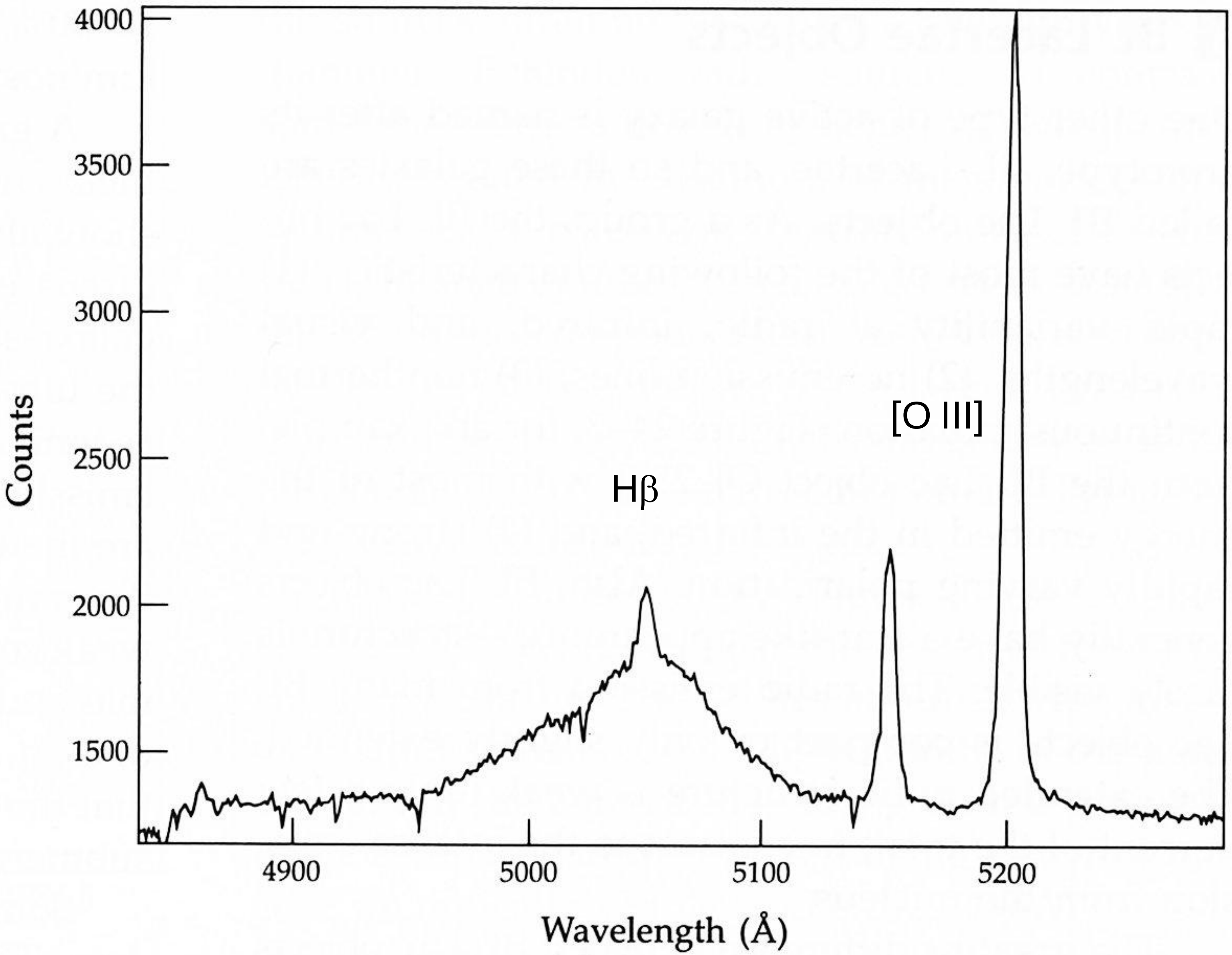


Optical image
of quasar



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

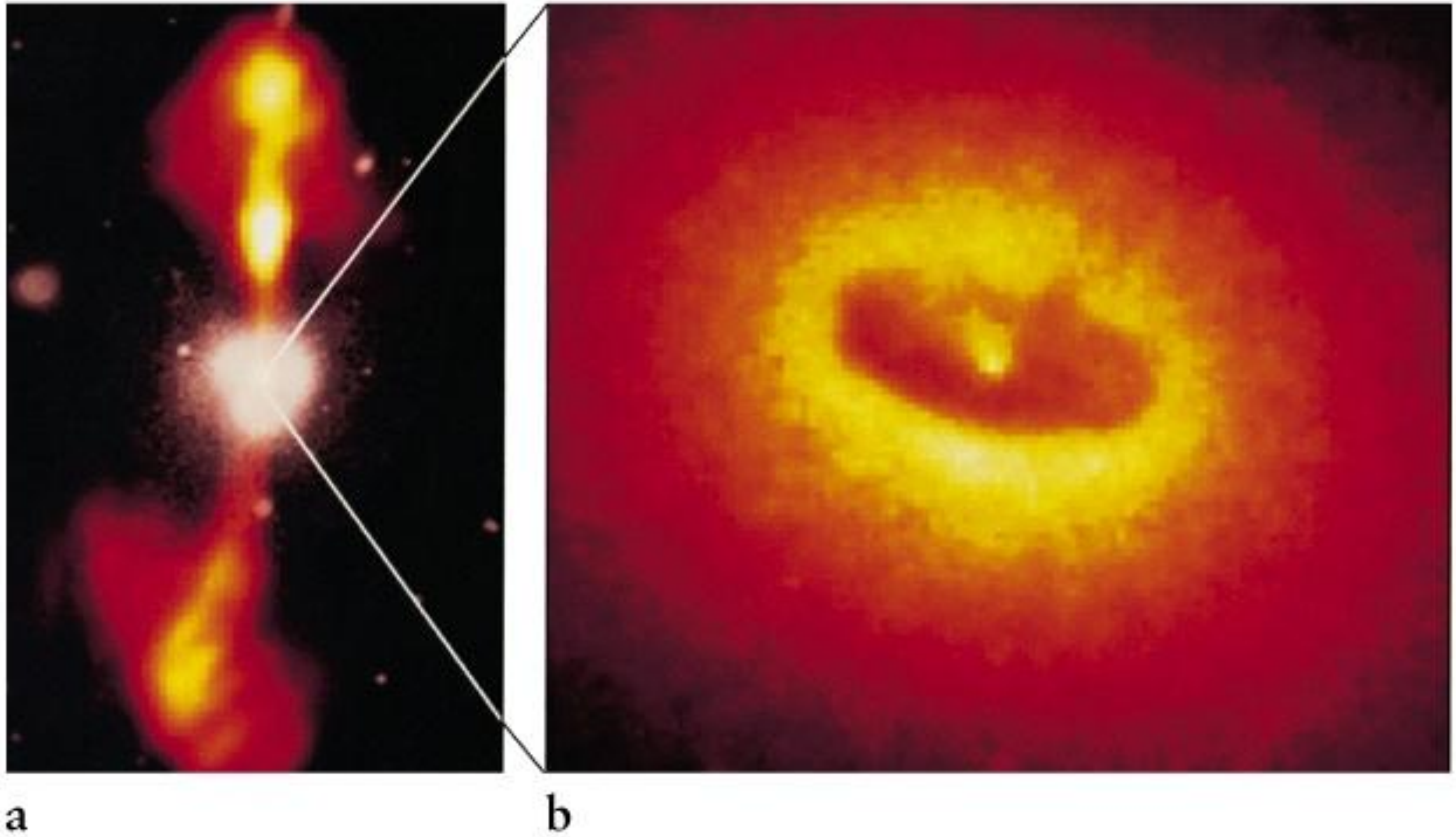
- The nucleus has a non-thermal continuum spectrum that extends from radio to X-rays
- Also has an emission line spectrum where the Balmer lines are often seen to be very broad



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



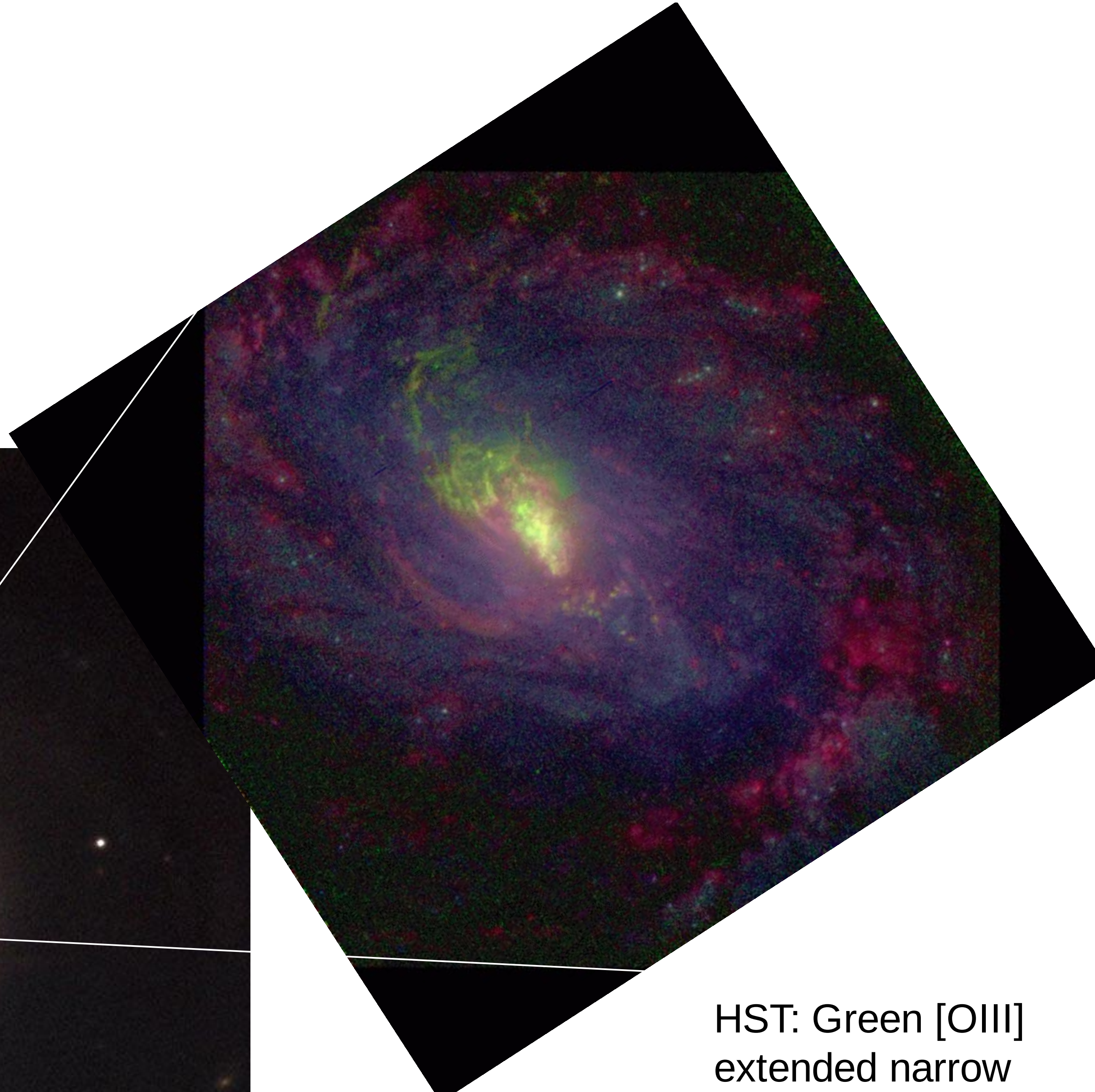
NGC 4261 Radio and Optical

NGC 4261 HST image of disc around the nucleus

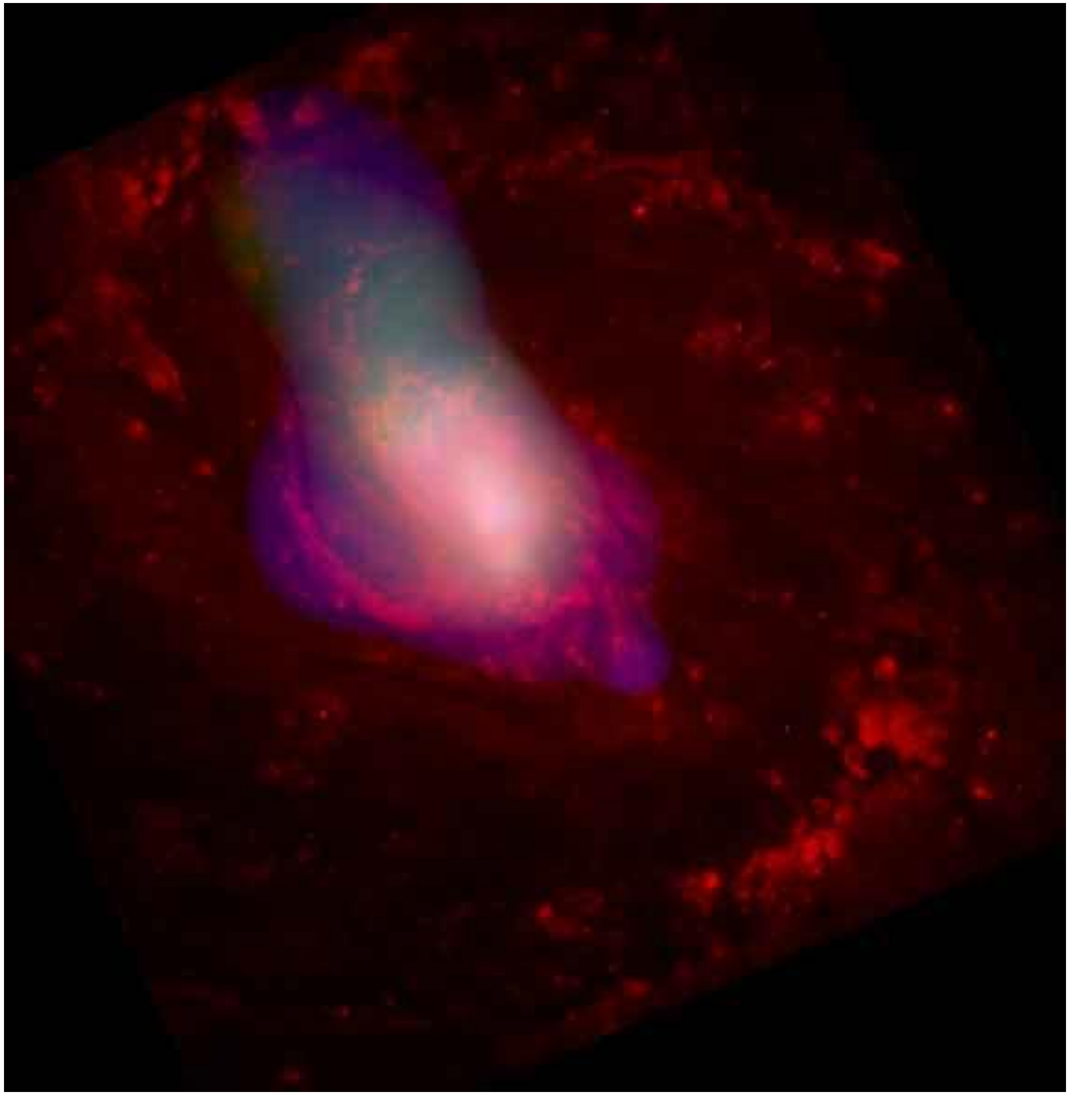
Credit: National Radio Astronomy Observatory, California Institute of Technology
Credit: Walter Jaffe/Leiden Observatory, Holland Ford/JHU/STScI, and NASA

NGC 1068

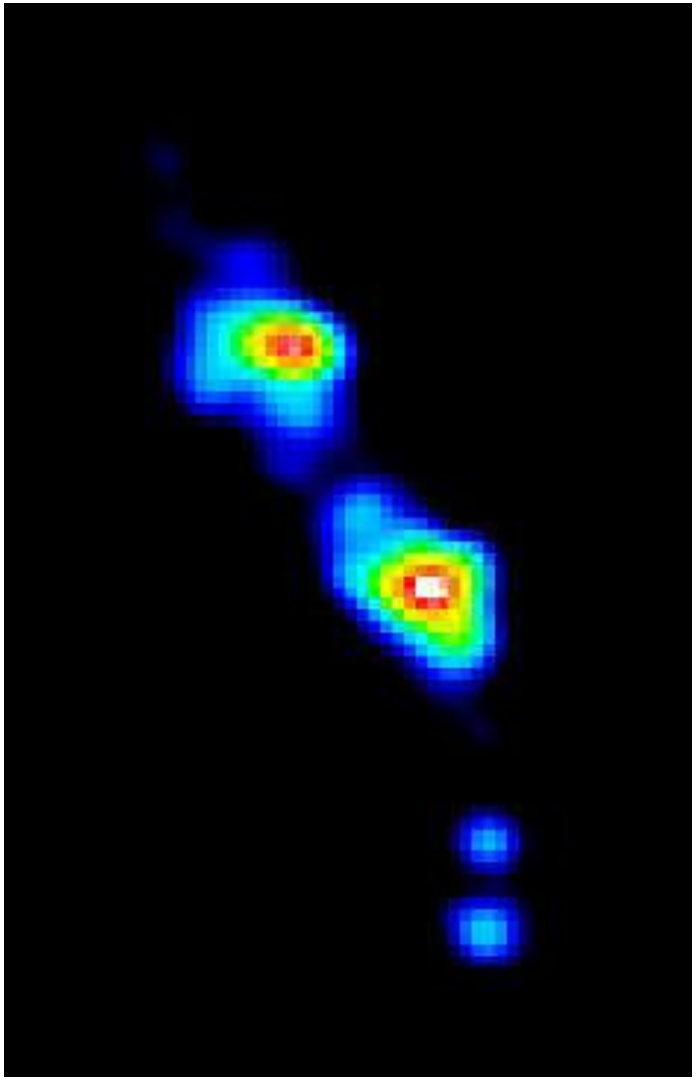
Seyfert 2



HST: Green [OIII] extended narrow line region



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



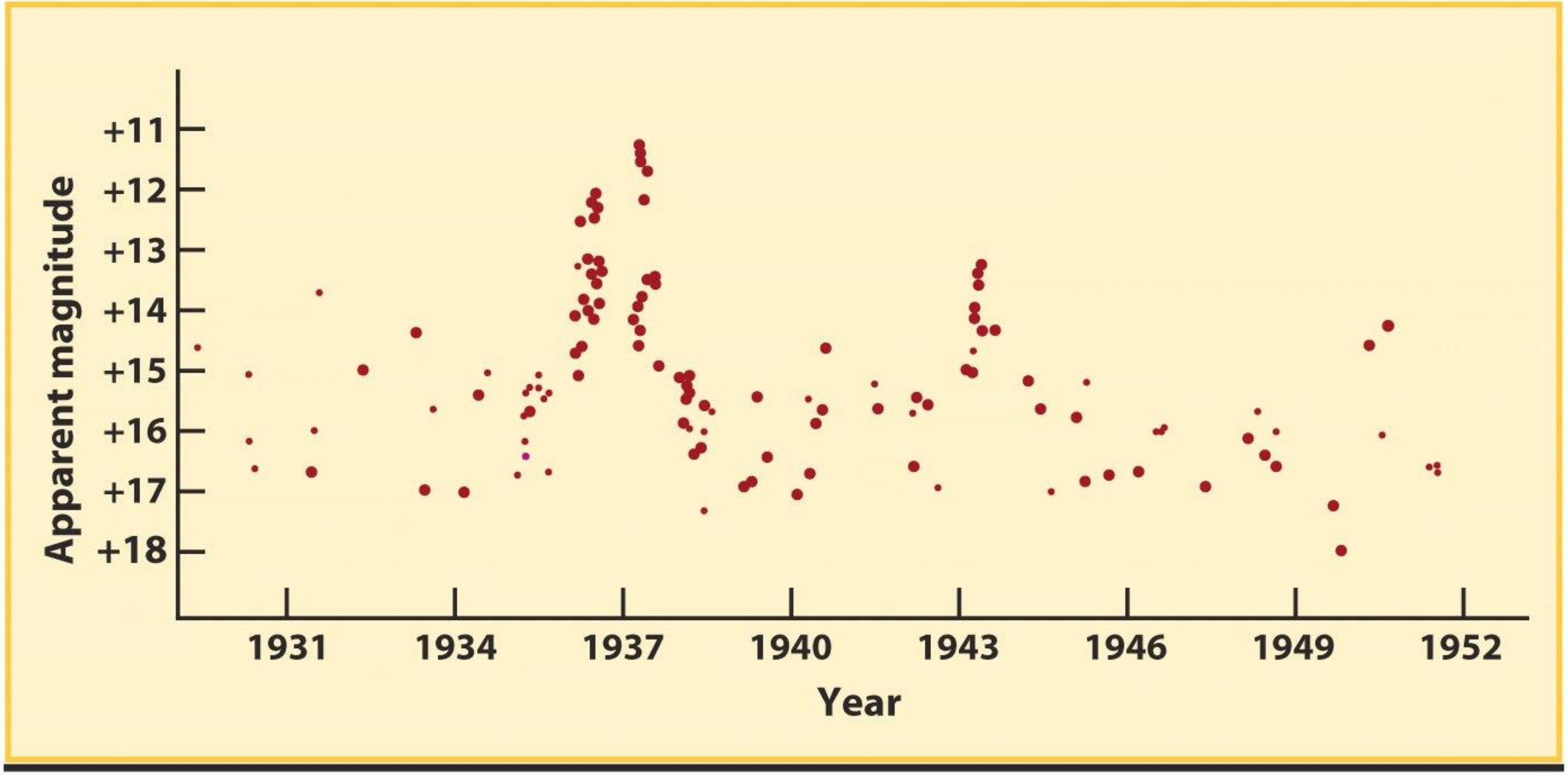
Radio: MERLIN 2 arcsec

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

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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

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

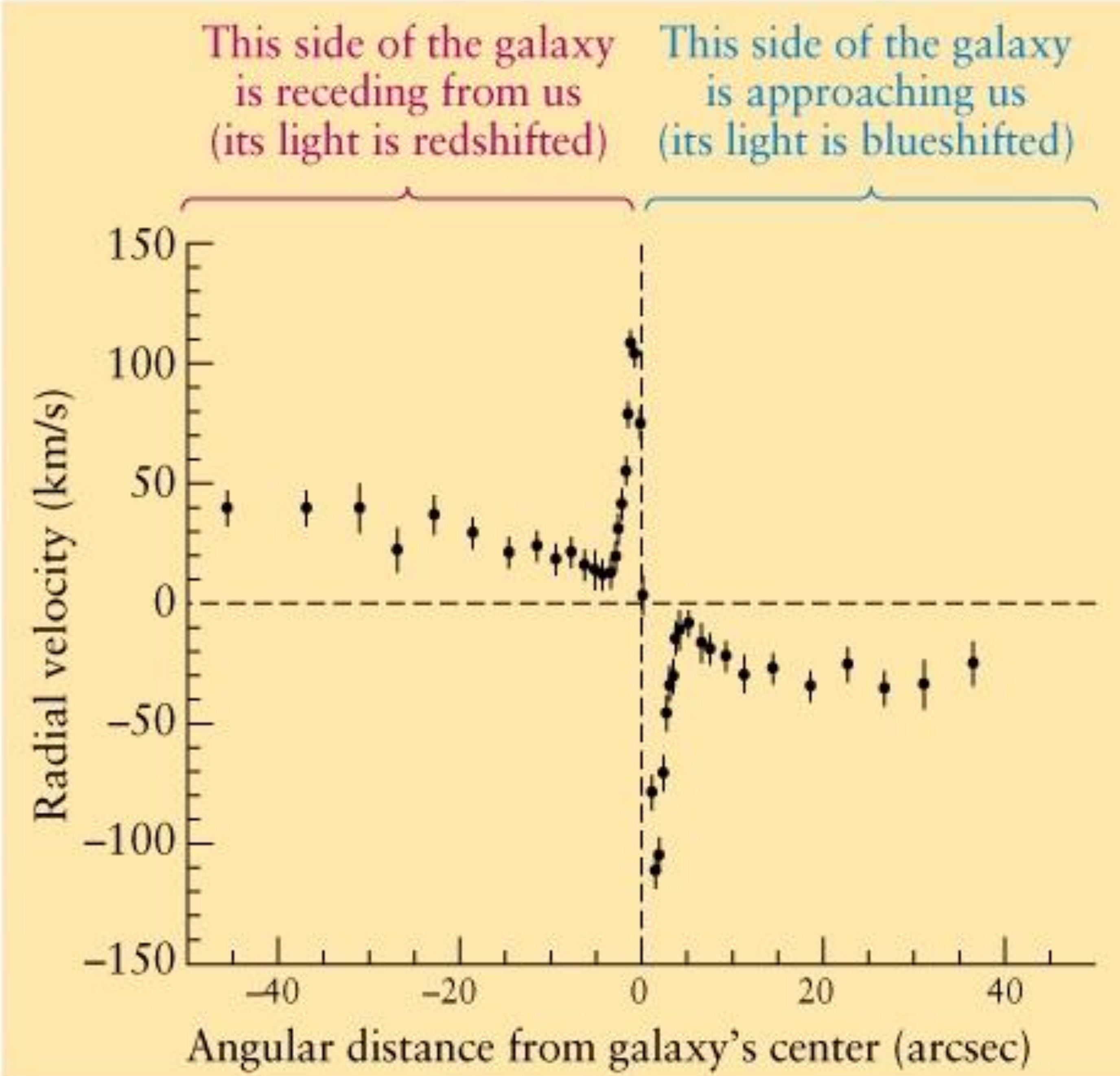
- If material gets to the Schwarzschild radius

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

- 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 posses central black holes, not just active ones, even our own



Stellar radial velocities in the core of M31

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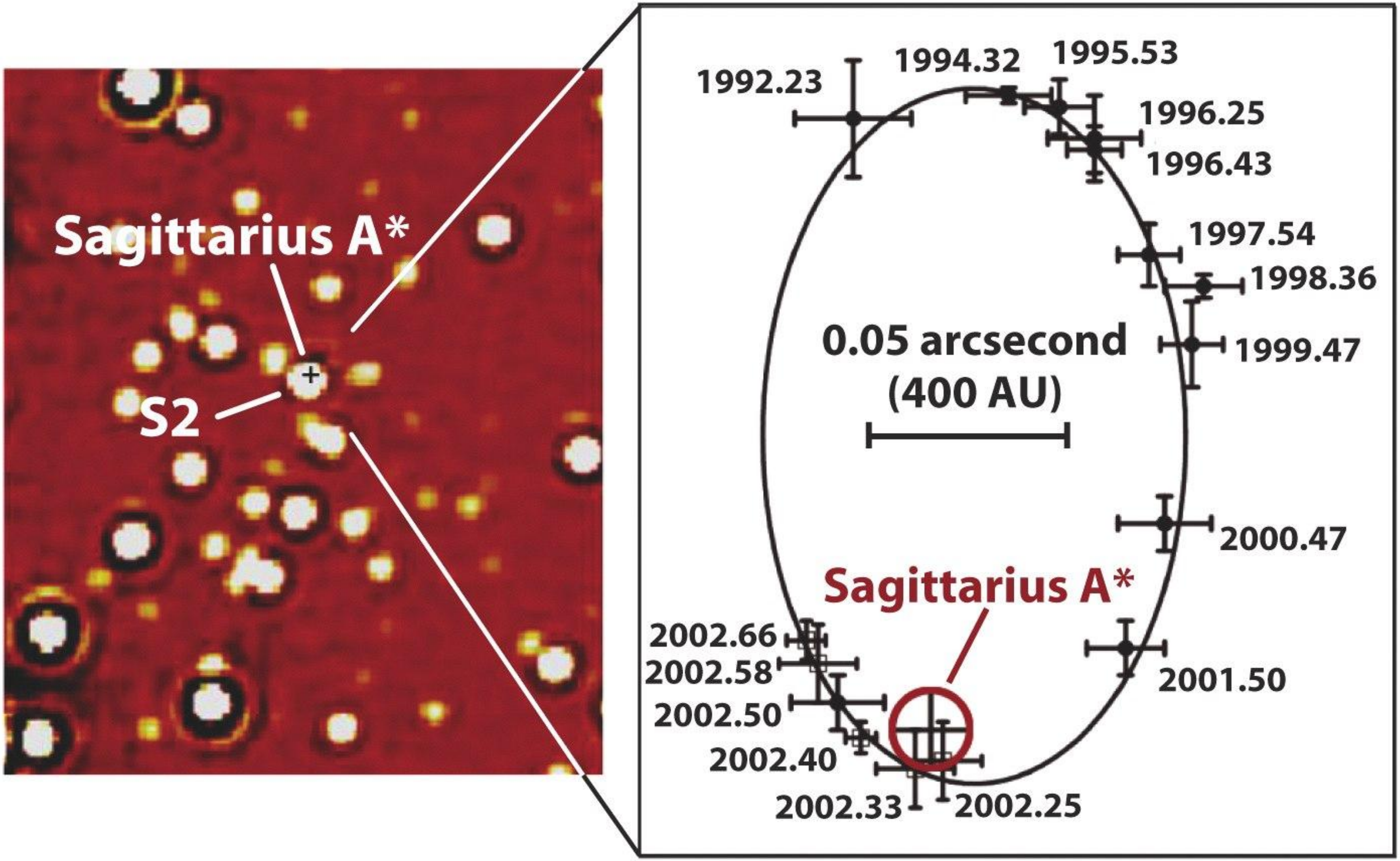
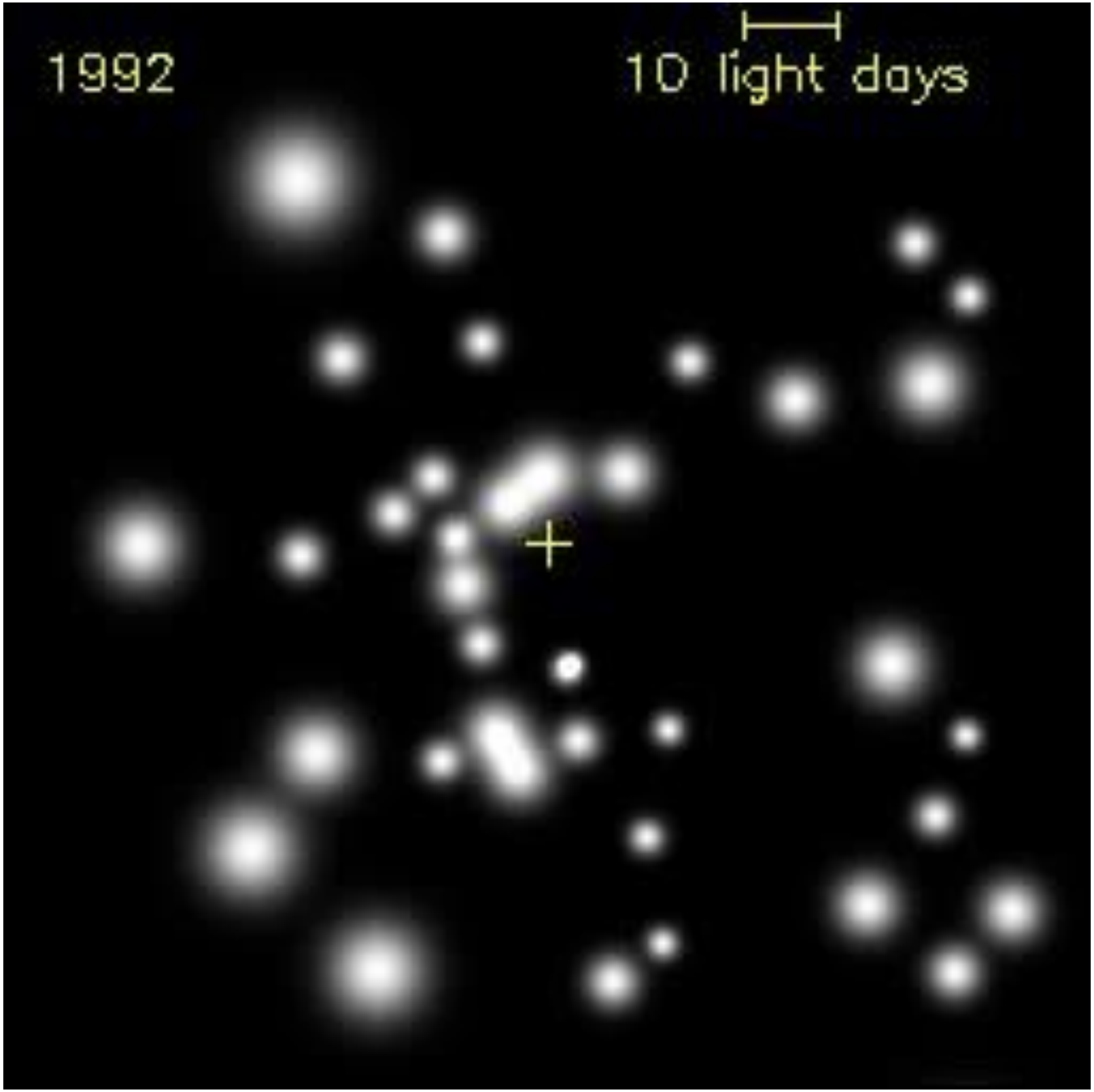


- Stellar orbits prove our Galaxy has a $4 \times 10^6 \, M_\odot$ black hole at the centre

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