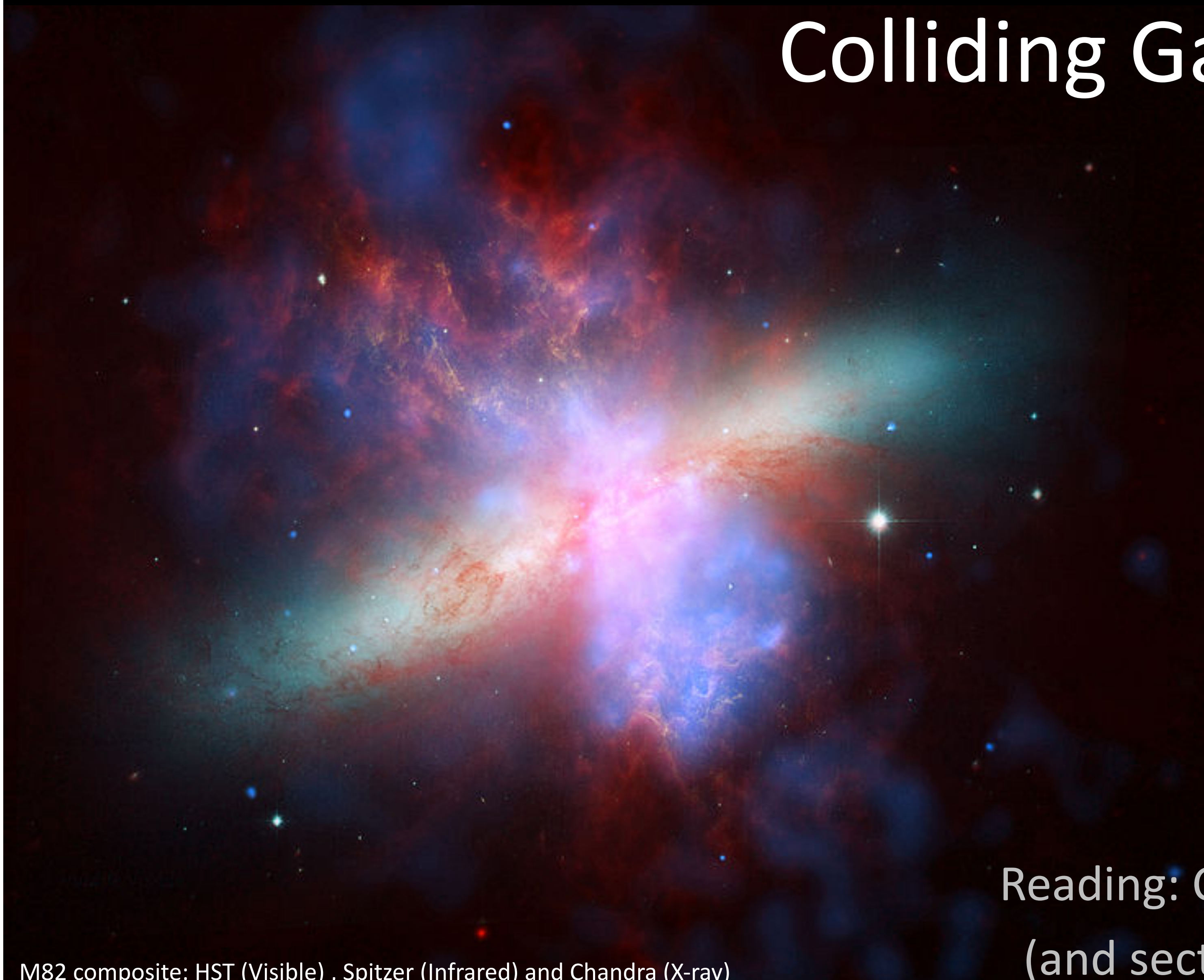
Active Galaxies, Colliding Galaxies



M82 composite: HST (Visible) , Spitzer (Infrared) and Chandra (X-ray)
(NASA/JPL-Caltech/STScI/CXC/UofA/ESA/AURA/JHU)

Reading: Chapter 24
(and section 23.1)

Active Galaxies

About 10% of observed galaxies emit much more energy than the rest

Energy seems to come from the core of the galaxy, so also referred to as Active Galactic Nuclei (AGN)

Bode's Galaxy (M81)
NASA/JPL

More AGN further away, hence back in time, so AGN may be a part of early evolution of all large galaxies.

Several different kinds of AGN found:

Seyfert galaxies, Radio Galaxies, IR galaxies, Quasars

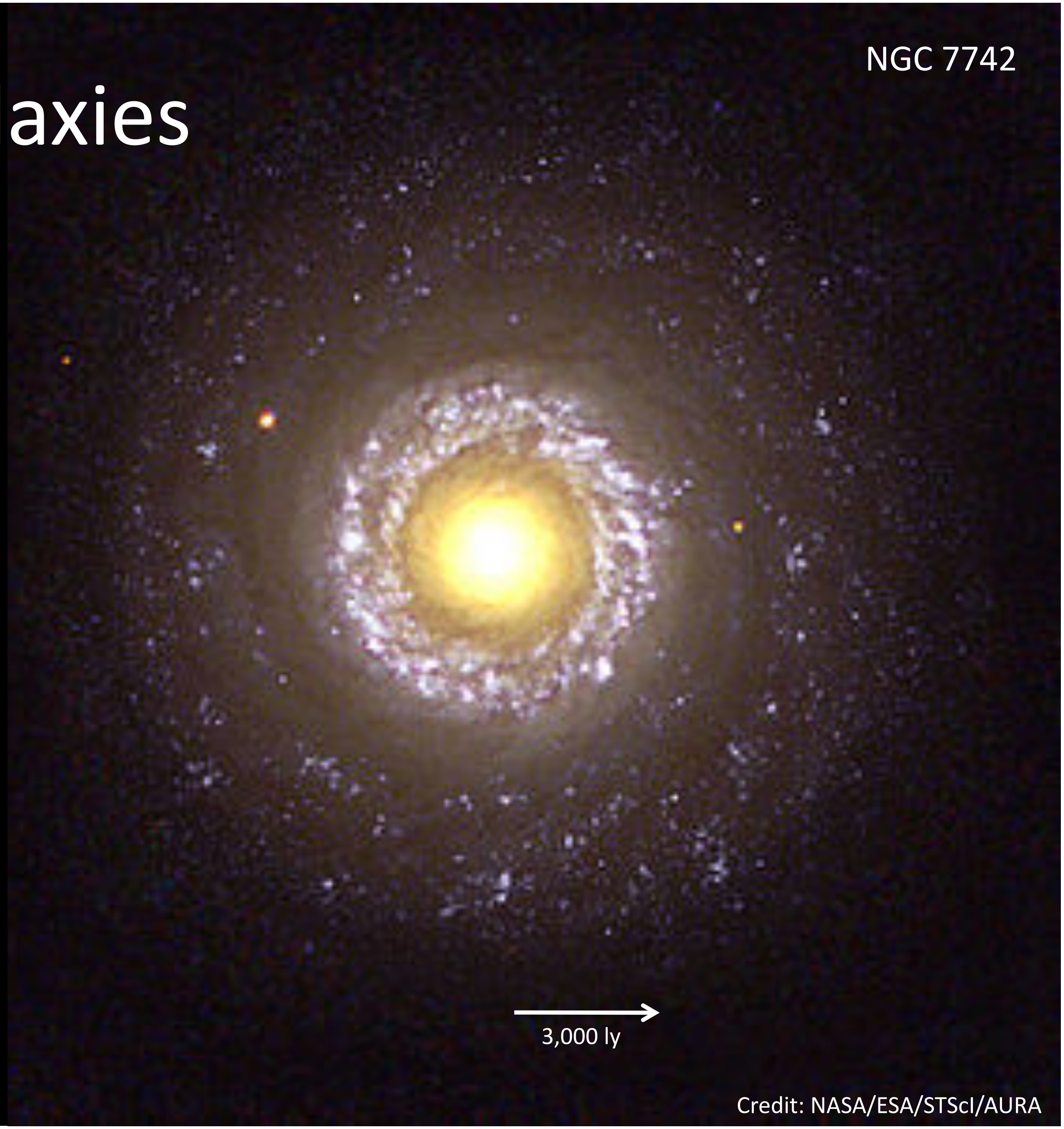
But all seem to have the same underlying cause:

a **Black Hole** at the center!

Seyfert Galaxies

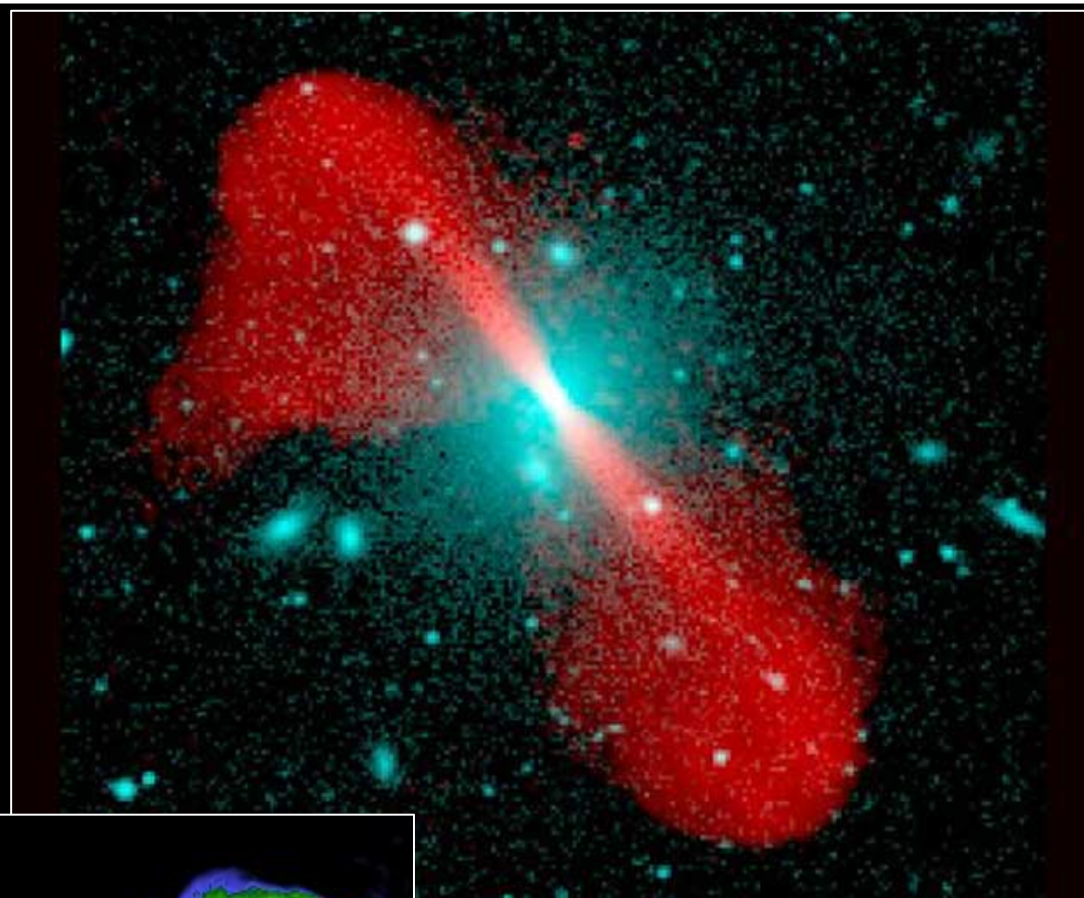
Seyfert galaxies are spiral galaxies with very bright centers.

First identified and classified in 1940's by Carl Seyfert

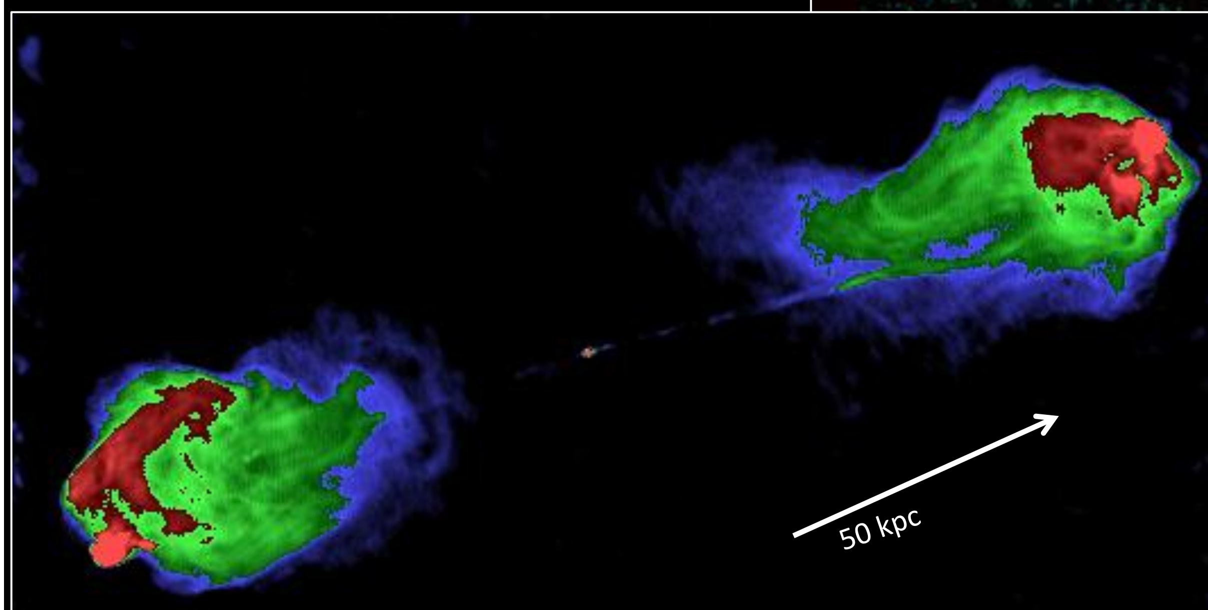


Radio Galaxies

Some very bright elliptical galaxies are also strong sources in the longer wavelength radio band



Composite image of NGC 5532 (3C 296), visible light in blue, radio in red



Cygnus A (3C 405), one of the strongest radio sources in the sky, and one of the first “radio stars” to be identified with an optical source.

Source: VLA data, 5 GHz

Infrared Galaxies

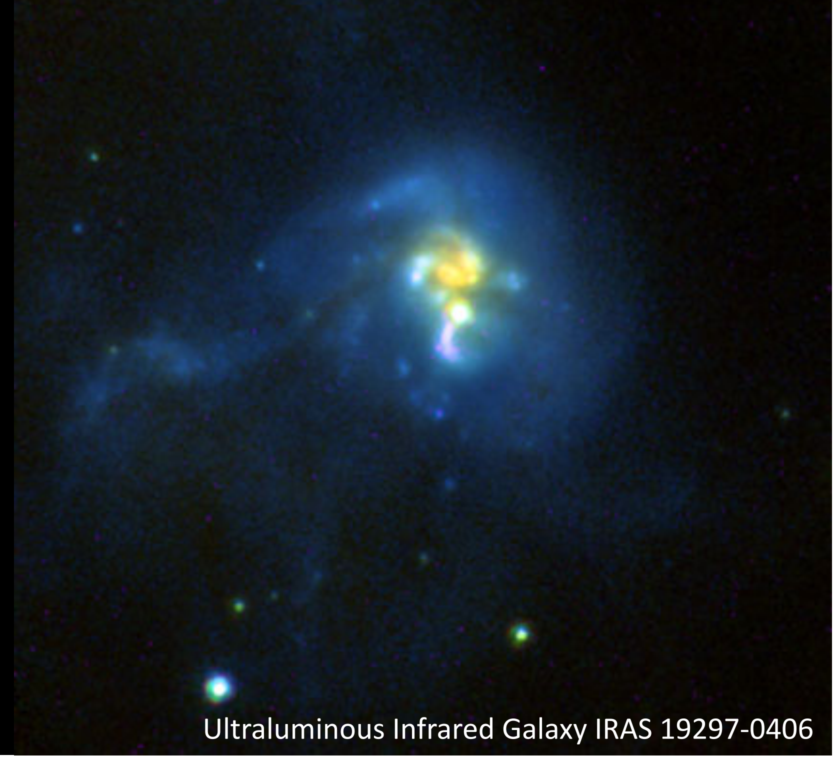
Infrared Astronomy Satellite (IRAS) found tens of thousands of galaxies with dominant energy output in the infrared spectrum. Now also called Luminous Infrared Galaxies (LIRG).

There are two types of IR galaxies:

Starburst galaxies, like M82, with much active star formation

Mosaic image of M82 from HST
Composite image using 4 filters

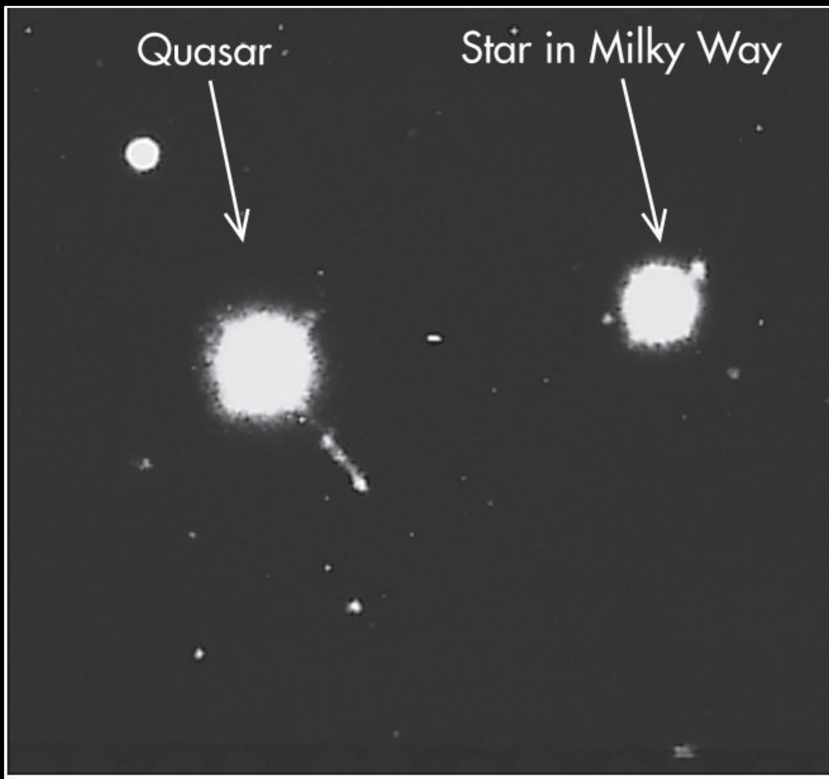
Ultraluminous IR galaxies, which may be dust-shrouded Quasars



Ultraluminous Infrared Galaxy IRAS 19297-0406

Quasars

Quasar = "Quasi-stellar Radio Source" or sometimes just "QSO"



Courtesy of NOAO; Courtesy of Tom Balonek and Jeyhan Kartaltepe, Colgate University

Mysterious objects until 1963, when Maarten Schmidt realized that spectral lines are red-shifted by an incredibly large amount

Large red shift means they are far away.

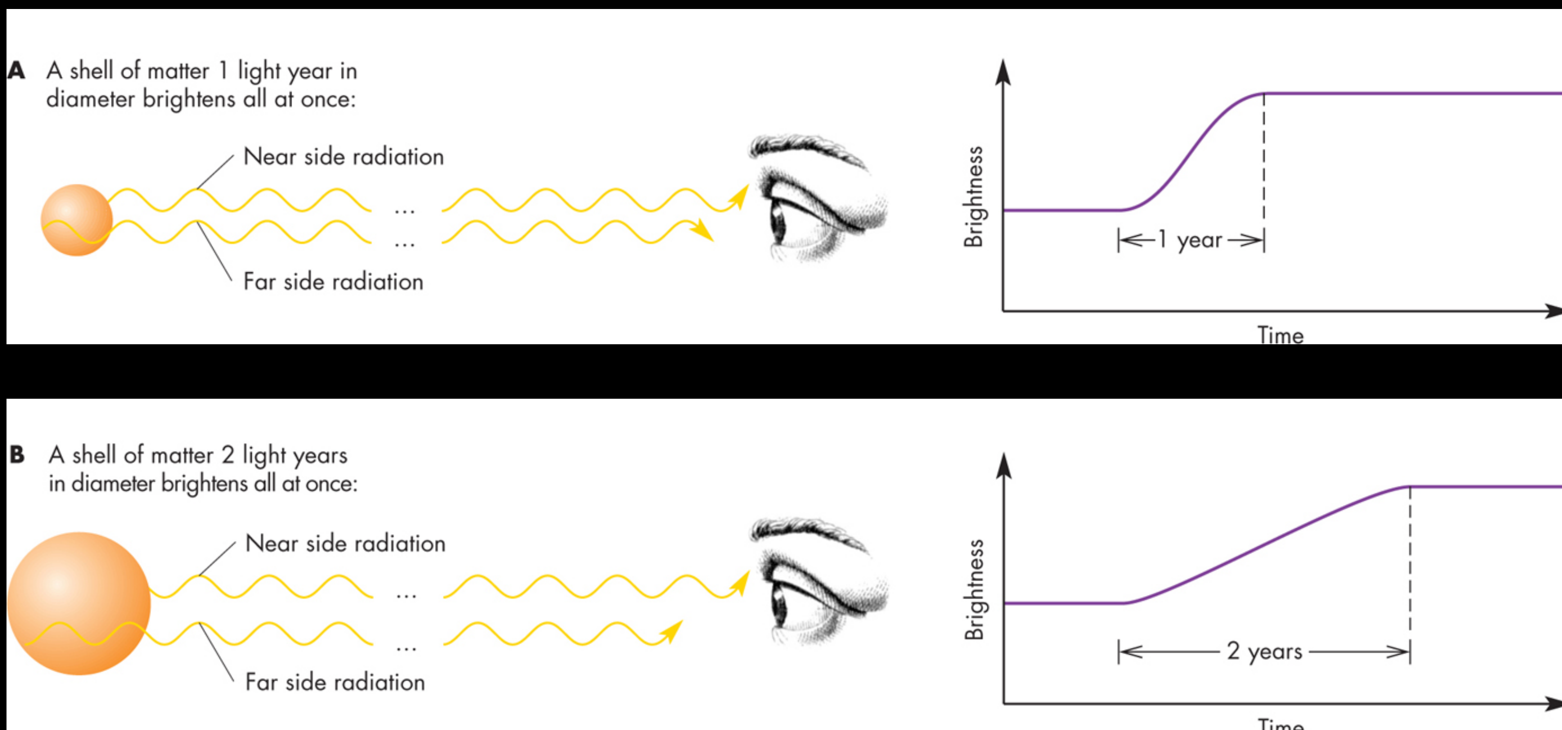
Measured luminosity at that great distance makes them incredibly bright objects:

> 1,000 to 10,000 times the total luminosity of the Milky Way!

Sizes, which are determined from brightness changes, are still very small.

Size and Light Variability

The time it takes for an object to change brightness is suggestive of the size of the object (and provides an upper limit):



Rapid variation in Quasar brightness in X-rays shows that they are small, not just far away.

Red shift and lookback time

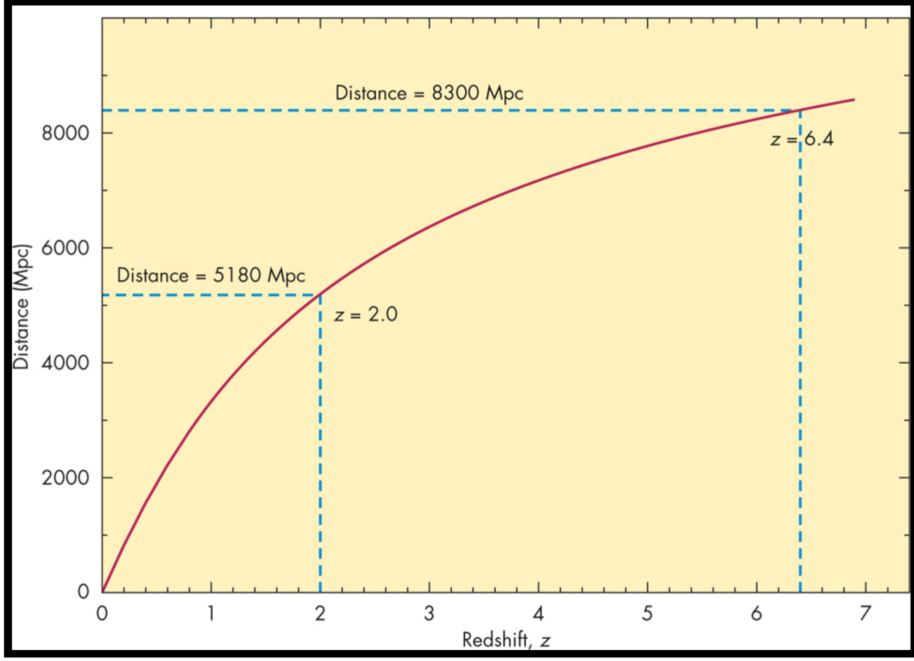
Astronomers use dimensionless *z* for red shift:

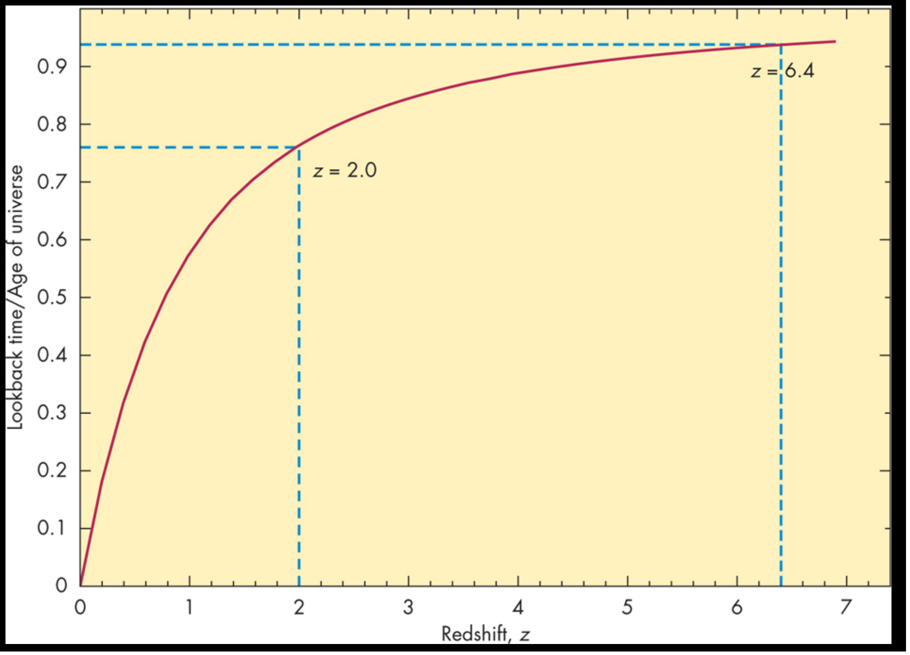
$$z = \frac{\lambda - \lambda_0}{\lambda_0}$$

By the Hubble Law larger recessional velocities mean larger red shift, which means larger distance.

The larger *z*, the larger the red shift (and negative values mean a blue shift)

One can turn red shift into both distance and "lookback time"



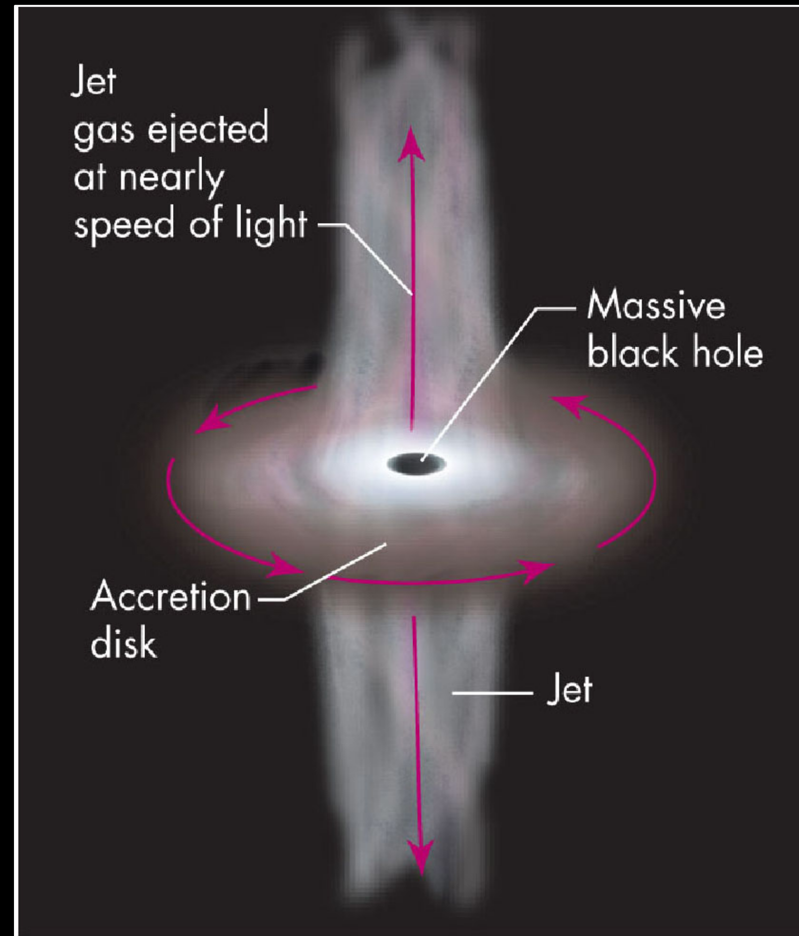


Black Hole Power!

Material falling into the black hole forms an accretion disk.

Material closest to black hole is compressed and heated to millions of degrees K.

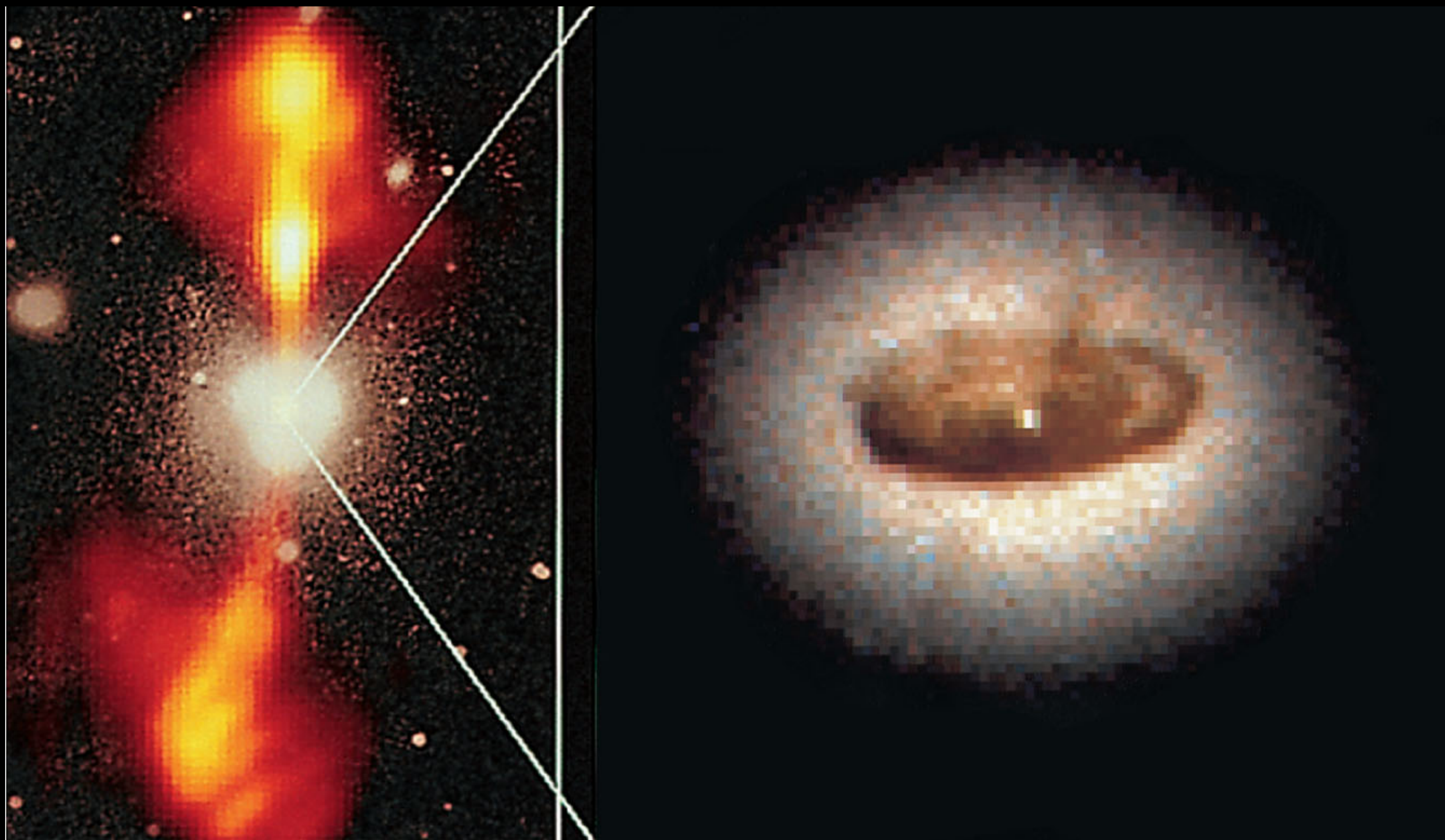
Most material falls into black hole, but some “boils off” and escapes.



Since the accretion disk blocks the sides, material flows out as bipolar jets, which also line up with magnetic field.

Artist's rendering of ULAS J1120+0641
Credit: ESO/M. Kornmesser

NGC 4261

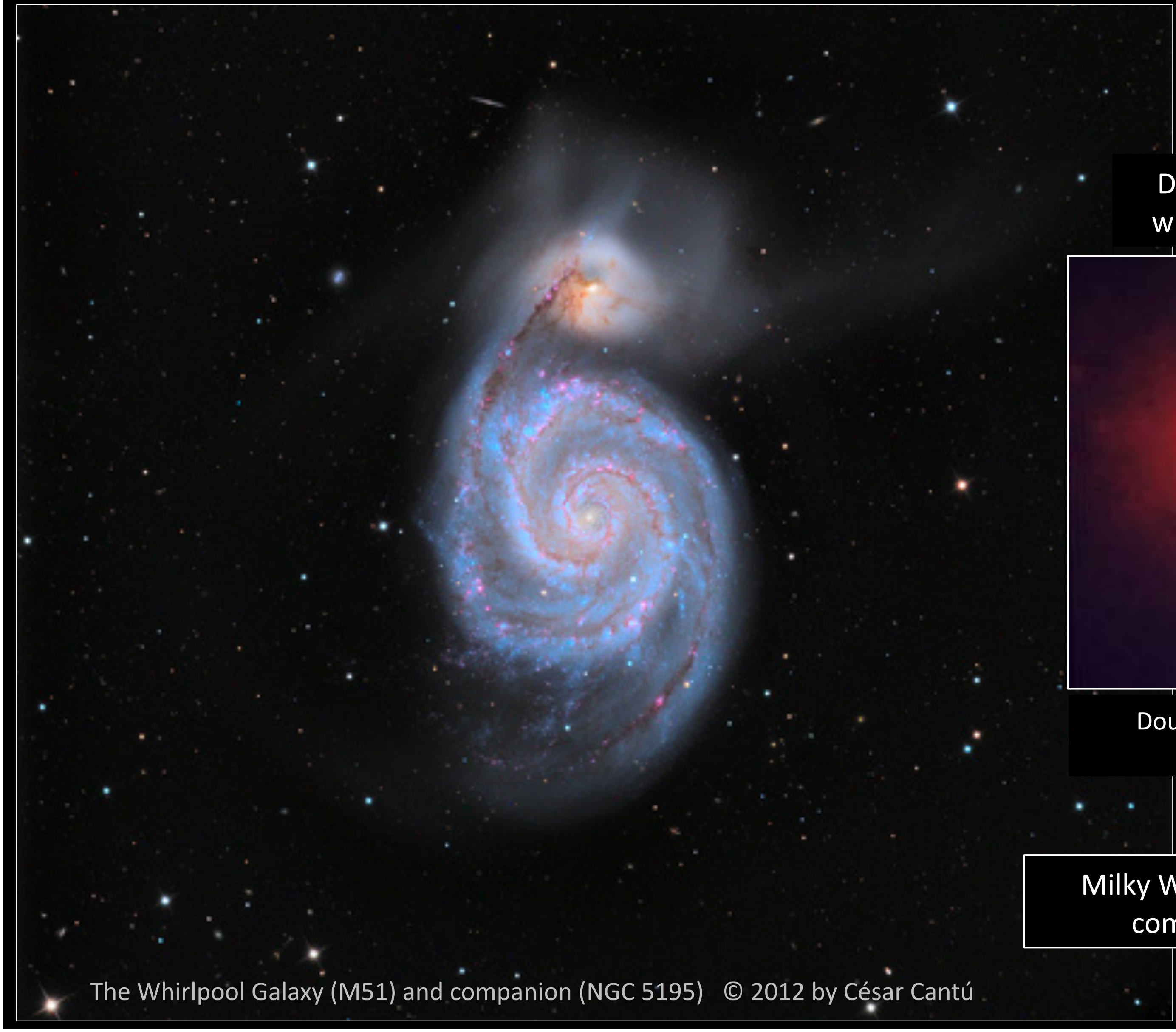


(left): Courtesy of W. Jaffe, Leiden Observatory, and H. Ford, Johns Hopkins University, Space Telescope Science Institute and NASA; (right): Courtesy of NRAO and California Institute of Technology

Left: composite optical / radio image shows radio jets extending outward from central galaxy

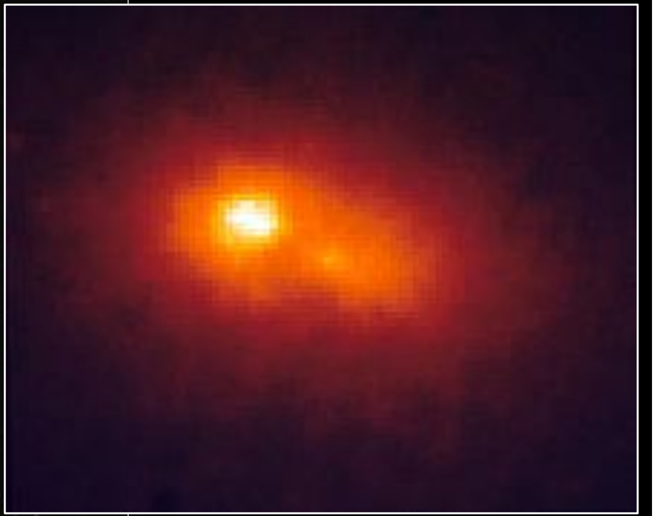
Right: HST visible images shows dark accretion disk around the central black hole

Collisions and Mergers



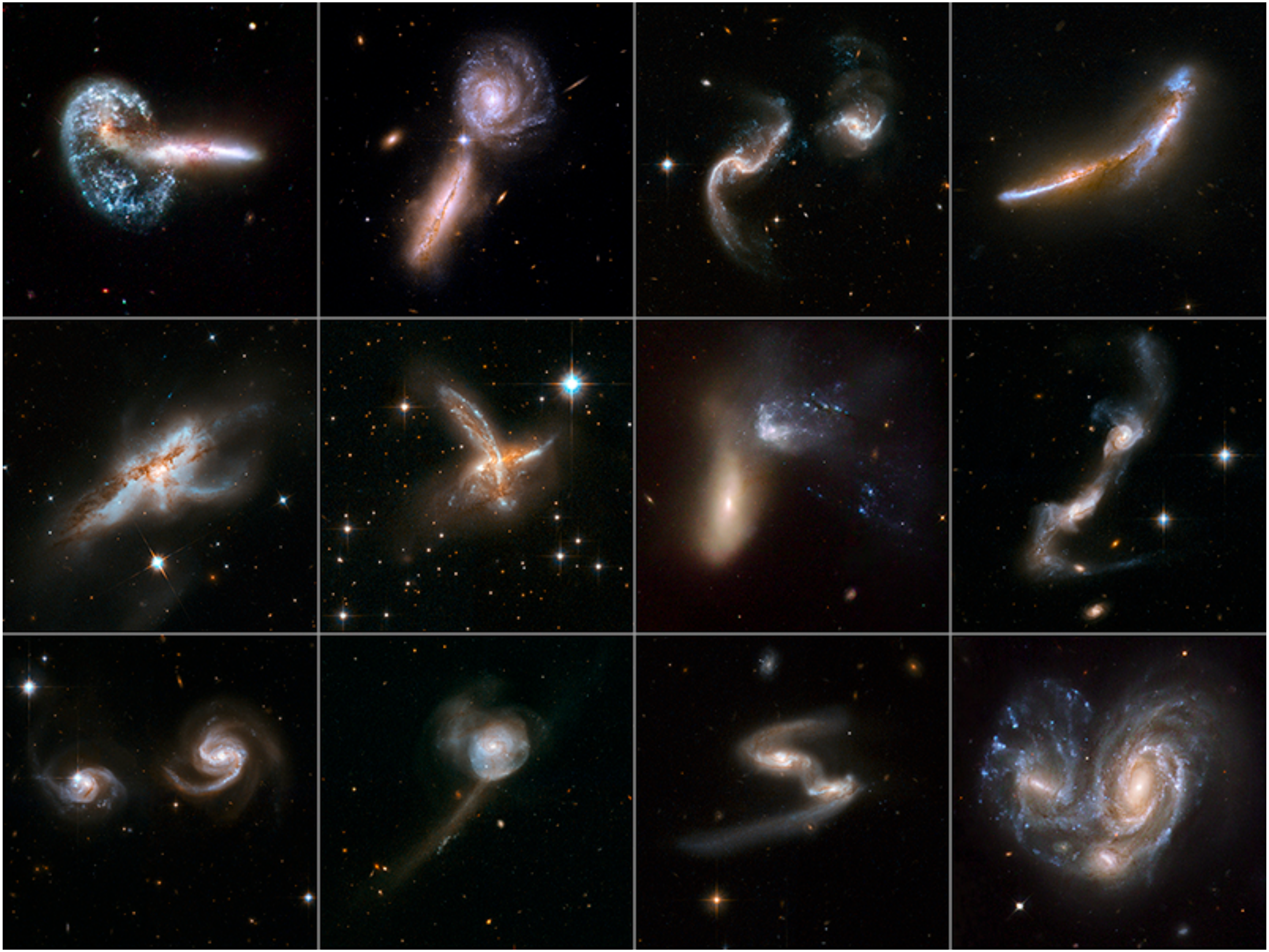
The Whirlpool Galaxy (M51) and companion (NGC 5195)   © 2012 by César Cantú

Did the Andromeda Galaxy collide with another in the "recent" past?



Double nucleus of the Andromeda Galaxy (Todd Lauer/NASA/ESA)

Milky Way and Andromeda Galaxies will come together in 1 to 3 billion years



Simulations

Simulation of major galaxy mergers

Milky Way and Andromeda

Two galaxies the size of the Milky Way,
modeled with Universe Sandbox

Collisions of Clusters

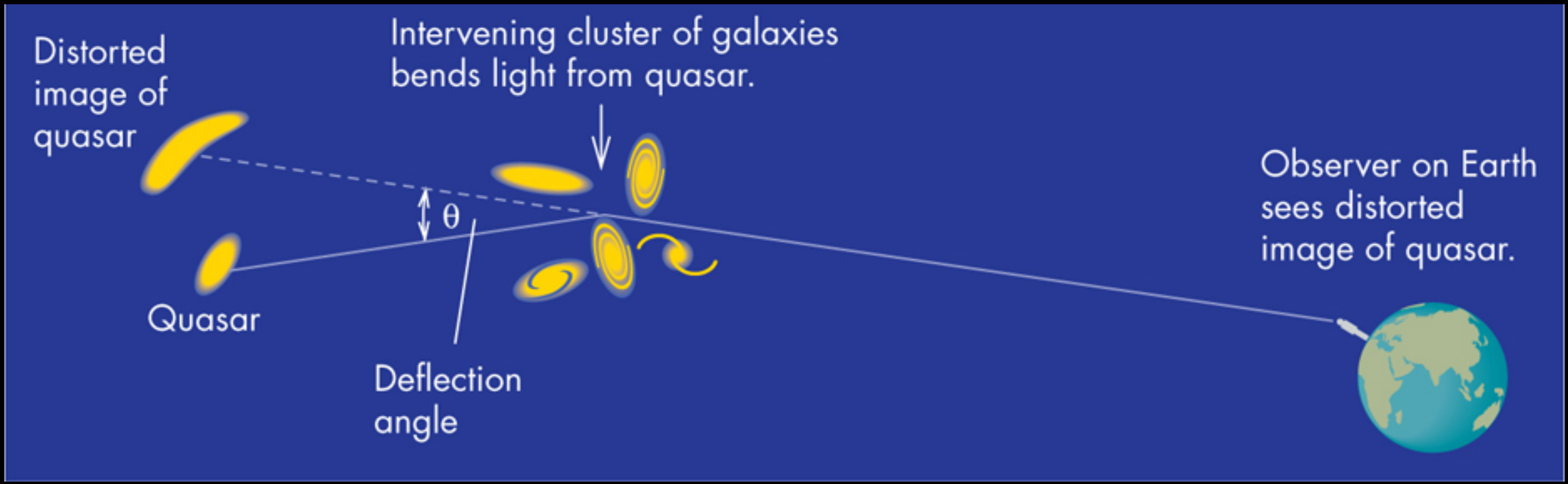
Abell 520 is actually two clusters of galaxies colliding

Distance: 2.4 billion light years

Orange: visible light , Green: X-rays from Chandra, Blue: dark matter distribution, from Hubble observations

March 2, 2012 Image credit: NASA, ESA, CFHT, CXO, M.J. Jee (University of California, Davis), and A. Mahdavi (San Francisco State University)

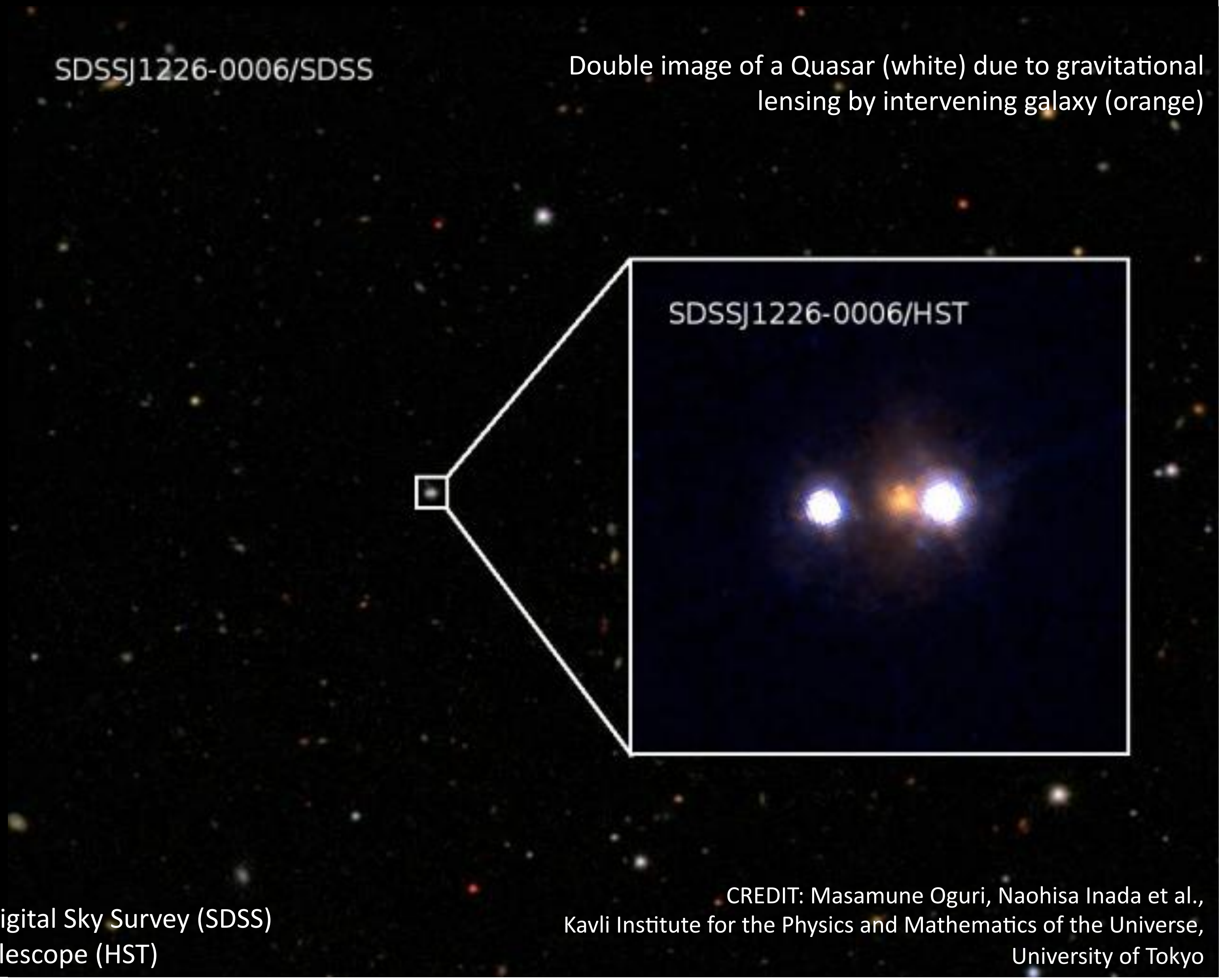
Gravitational Lensing



Gravitational Lens

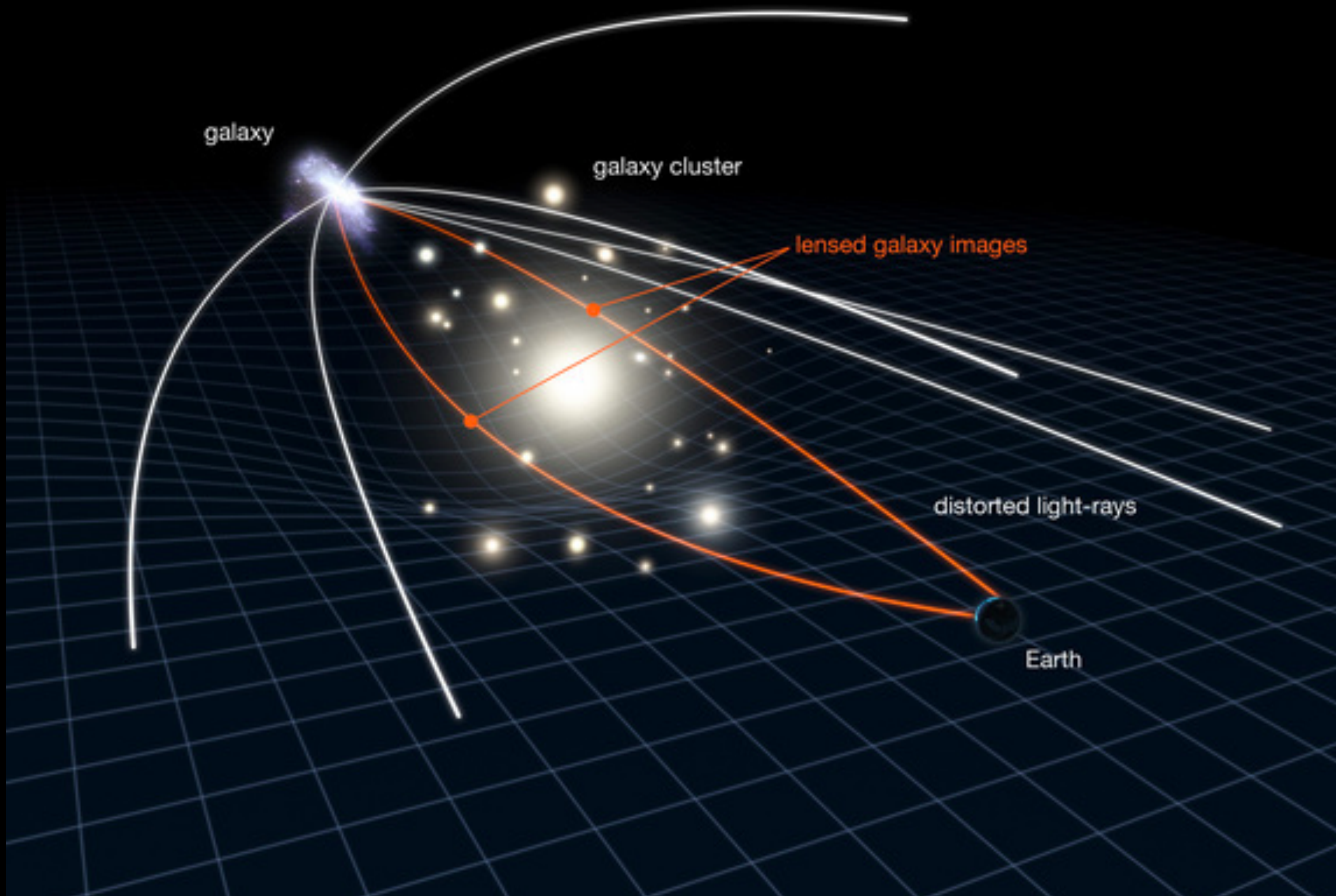
12 April 2012

Double image of a Quasar (white) due to gravitational lensing by intervening galaxy (orange)



Larger picture: Sloan Digital Sky Survey (SDSS)
Inset: Hubble Space Telescope (HST)

CREDIT: Masamune Oguri, Naohisa Inada et al.,
Kavli Institute for the Physics and Mathematics of the Universe,
University of Tokyo



http://www.livescience.com/19645-universe-acceleration-dark-energy-quasars.html