Luminosity function of quasars

The number of quasars per unit co-moving volume whose absolute magnitude lies between M and M+dM.

The co-moving volume is a volume that expands with the expansion of the universe. This allow us to test if QSOs were more numerous or luminous in the past.

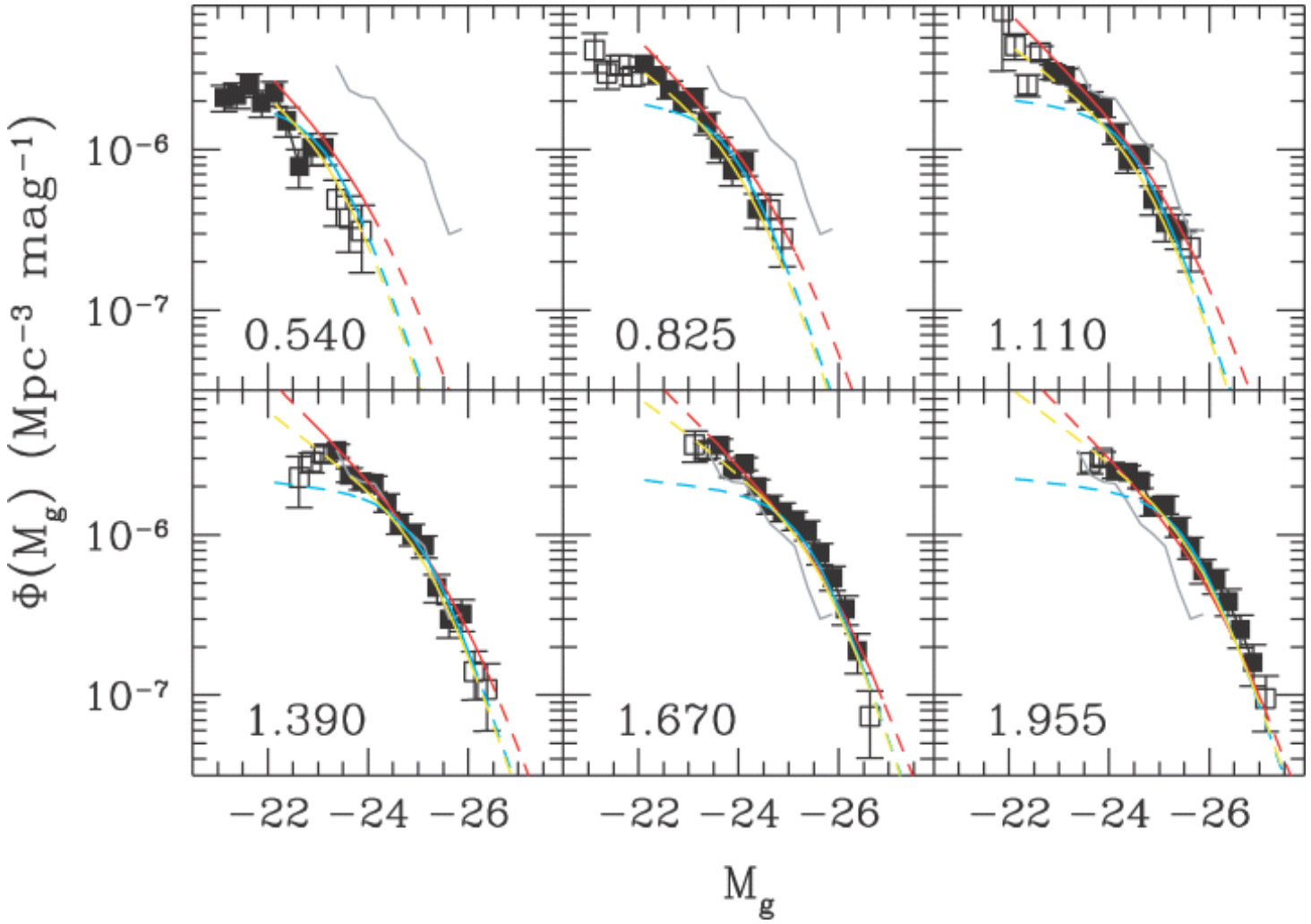
A strong evolution with z, and probably more luminous since not enough large galaxies to give so many quasars at z=2.

Quasars and Seyferts have similar luminosity evolution:

Same type of objects, just that Seyfert's less luminous!

Richards et al 2005:

Quasars brighter at higher redshifts



Radio properties of quasars

Although quasars were discovered through radio observations, most quasars are faint at radio wavelengths (called QSOs).

The radio structures of quasars usually have two main components:

- Compact (<1")
  - Flat-spectrum core
  - Optically thick
  - Bright optical source
  - One-sided jet on sub-arcsecond scales

- Extended (double lobe structure)
  - Steep-spectrum
  - Optically thin

Radio Galaxies

Radio surveys also found objects that are extremely bright at radio wavelengths. The optical nucleus is bright and small.

- Also show emission lines:
  - Broad line radio galaxies (BLRG)
  - Narrow line radio galaxies (NLRG)

- Optical host galaxies are ellipticals.

- Radio maps show lobes, jets, or core and halo.

- Power law spectra => synchrotron radiation

Nomenclature

Some confusing naming convention:

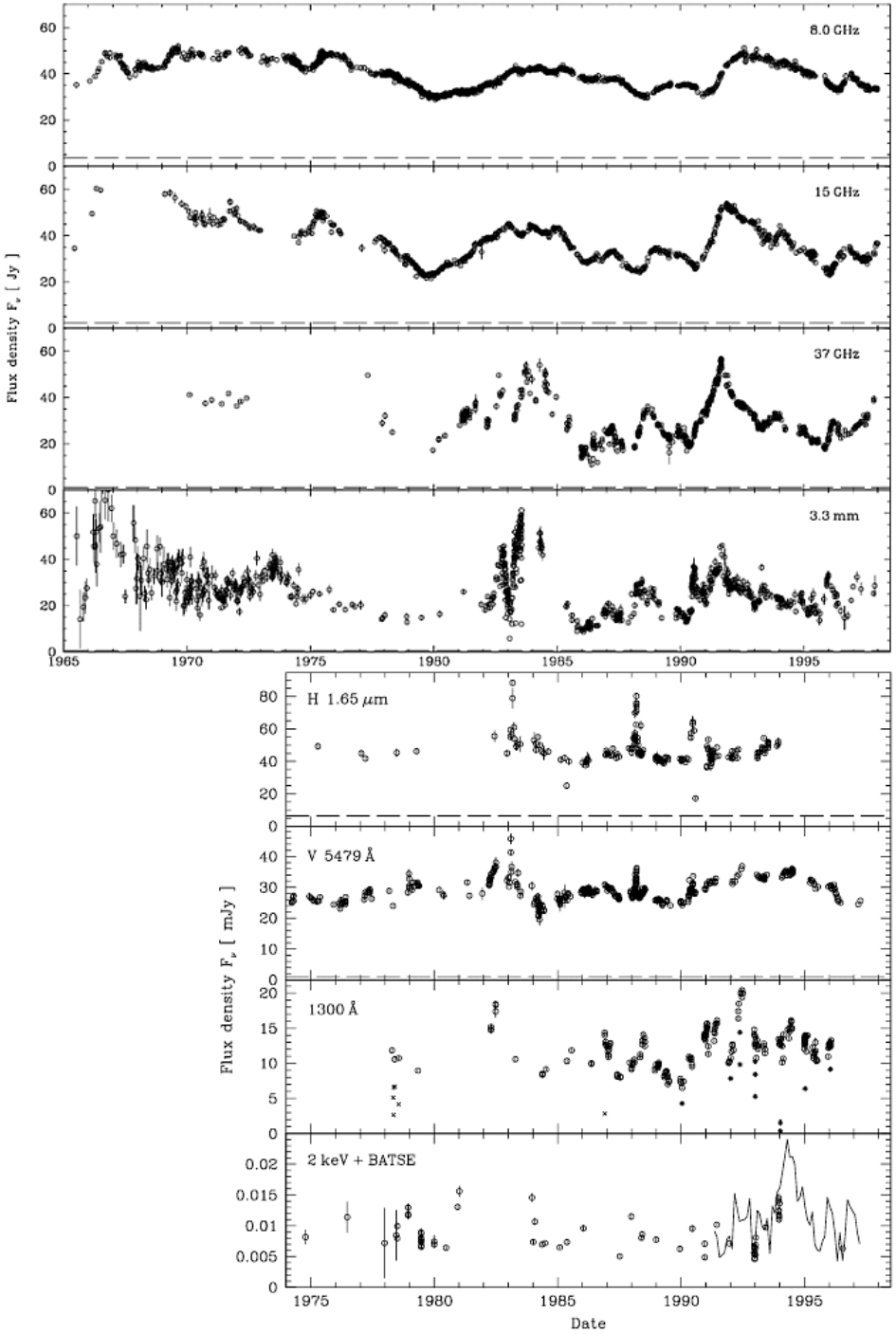
- Quasars with extended radio emission are generally called quasars.
- Quasars without radio emission are often called *QSOs*, quasi-stellar objects, but sometimes called quasars.
- There are many more names for the same object (OVV quasars, HPQ quasars, etc.)

Note that all of these are Active Galactic Nuclei (AGN)

Quasar variability

Quasars are variable in every waveband and in emission lines.

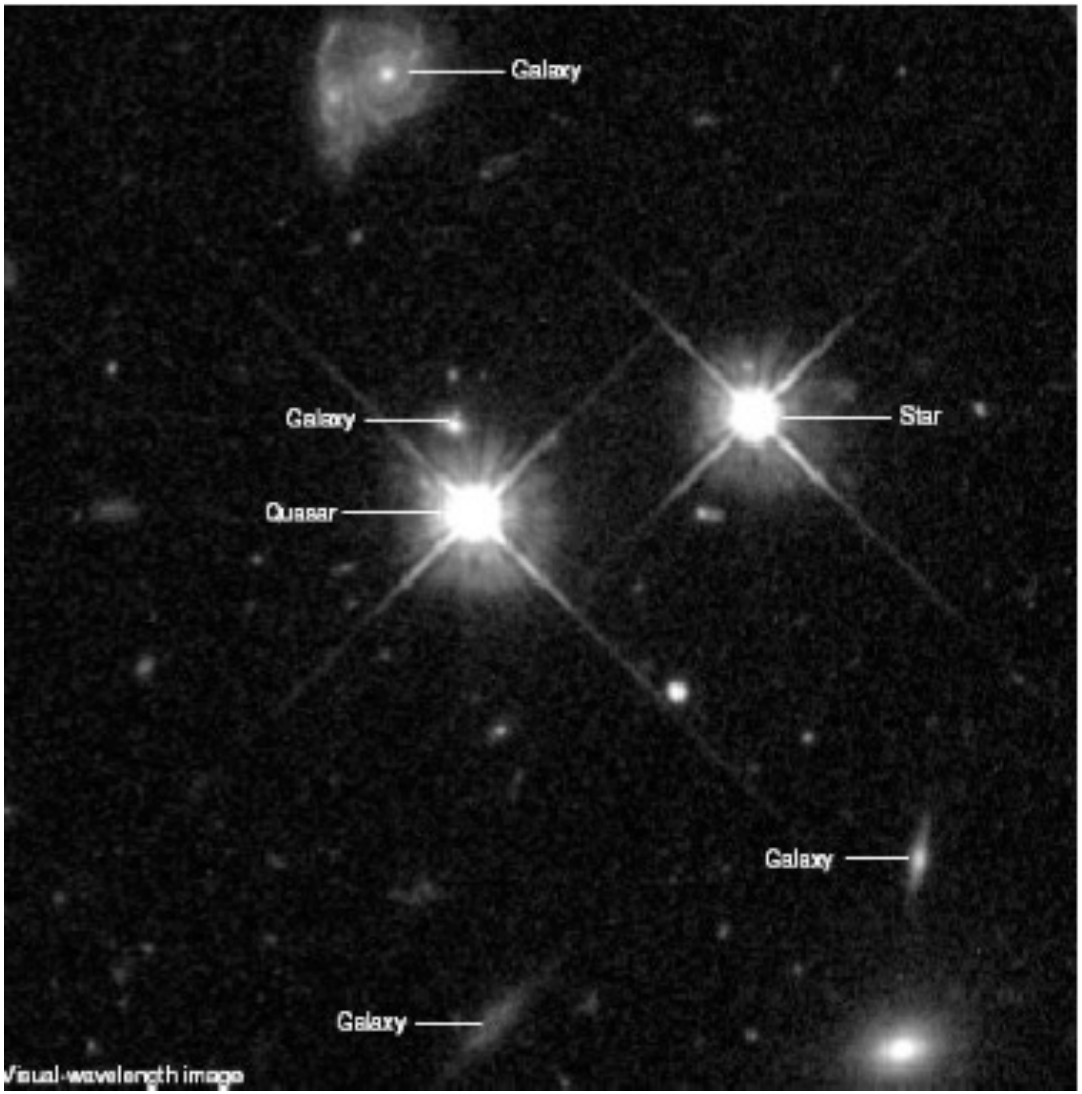
The variability time-scale can be days to months, hence the size of the emission region is light-days to light-months.



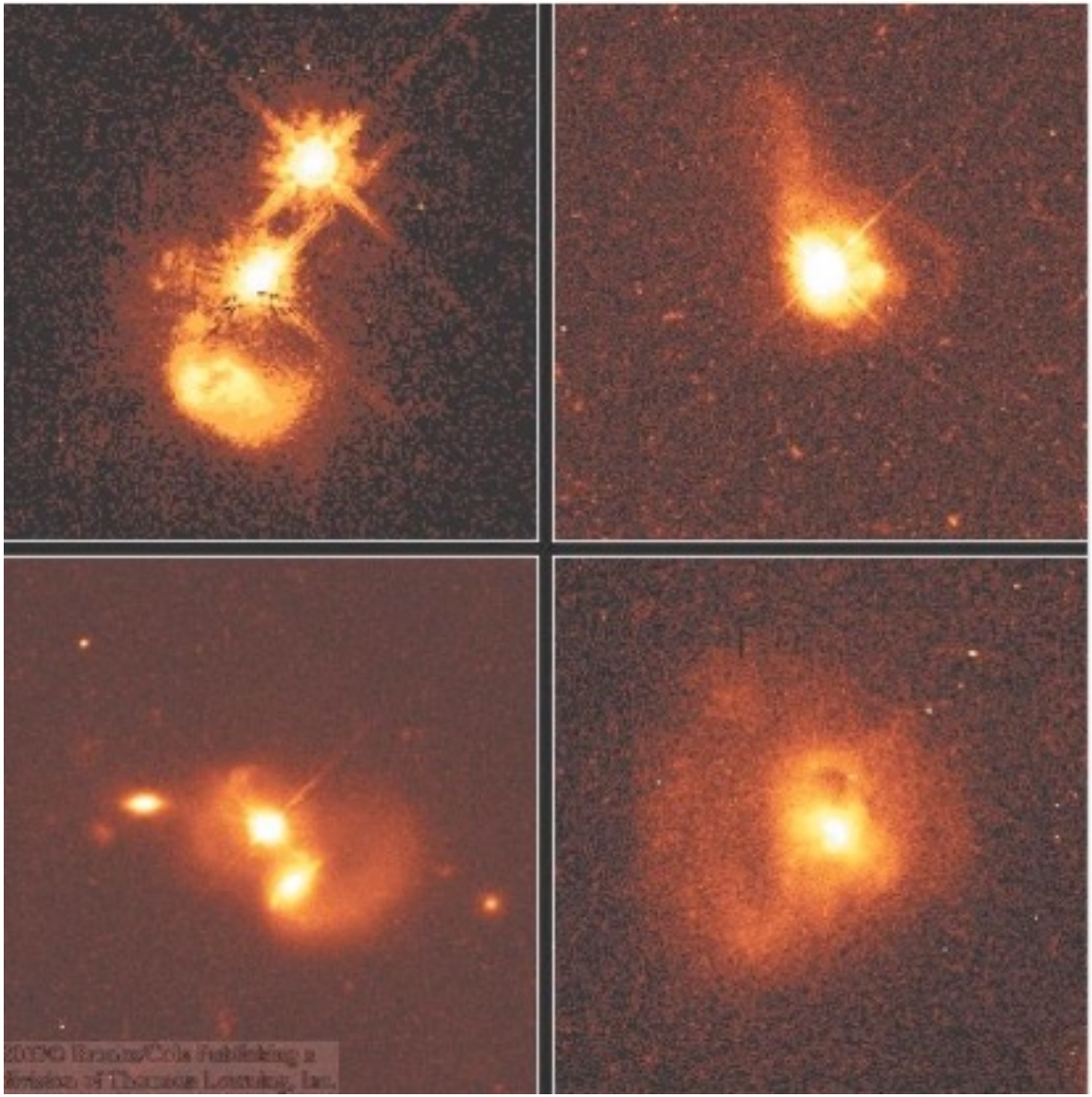
30 years of multi-wavelength observations of 3C273
Astron. Astrophys. Suppl. Ser. 134, 89-101
M. Türler et al. 1998 July 28 http://obswww.unige.ch/3c273/

Examples of QSOs

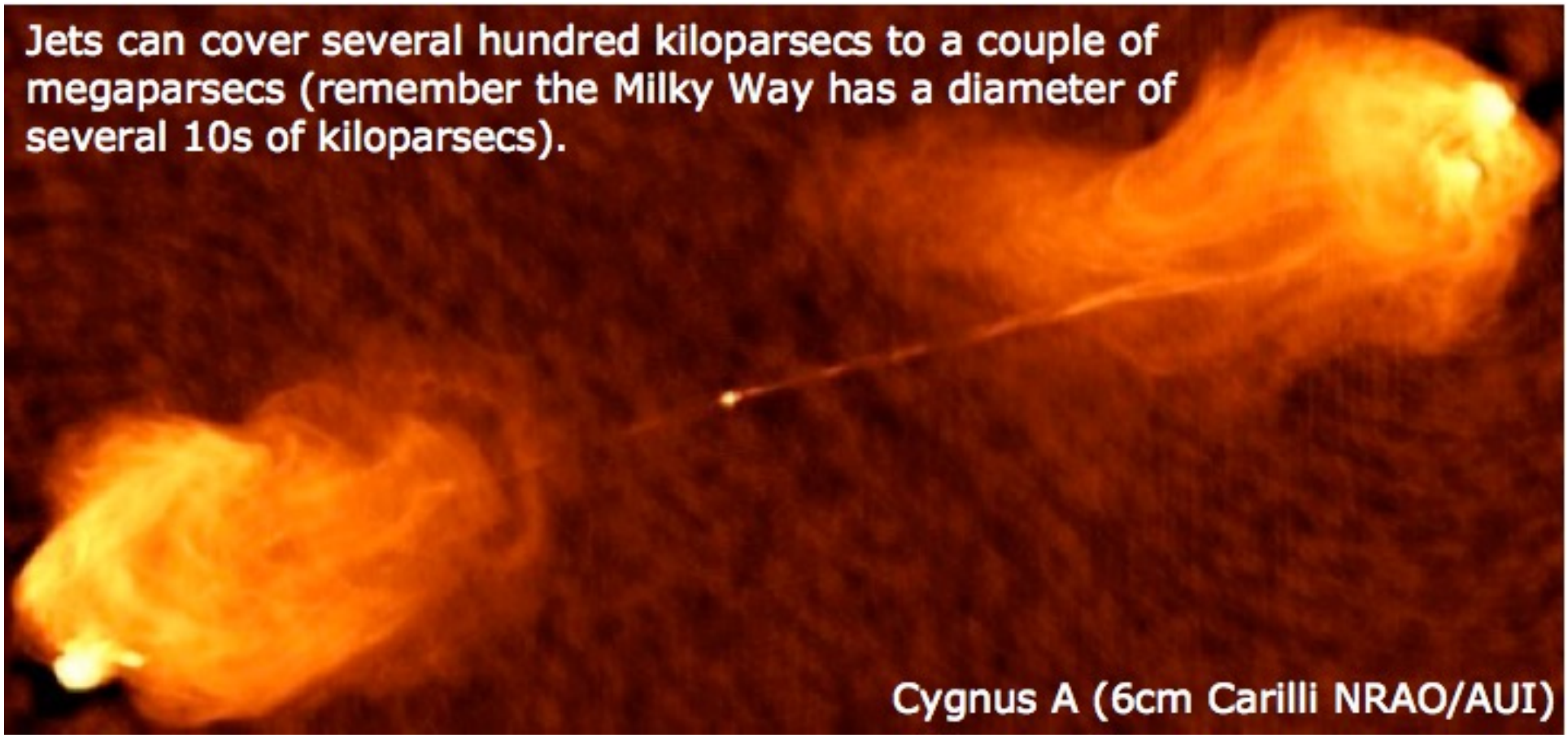
QSOs often outshine their host galaxies which can be difficult to detect.



Quasar host galaxies often show signs of interactions



Examples of radio galaxies: Cygnus A



Radio galaxies: main classes

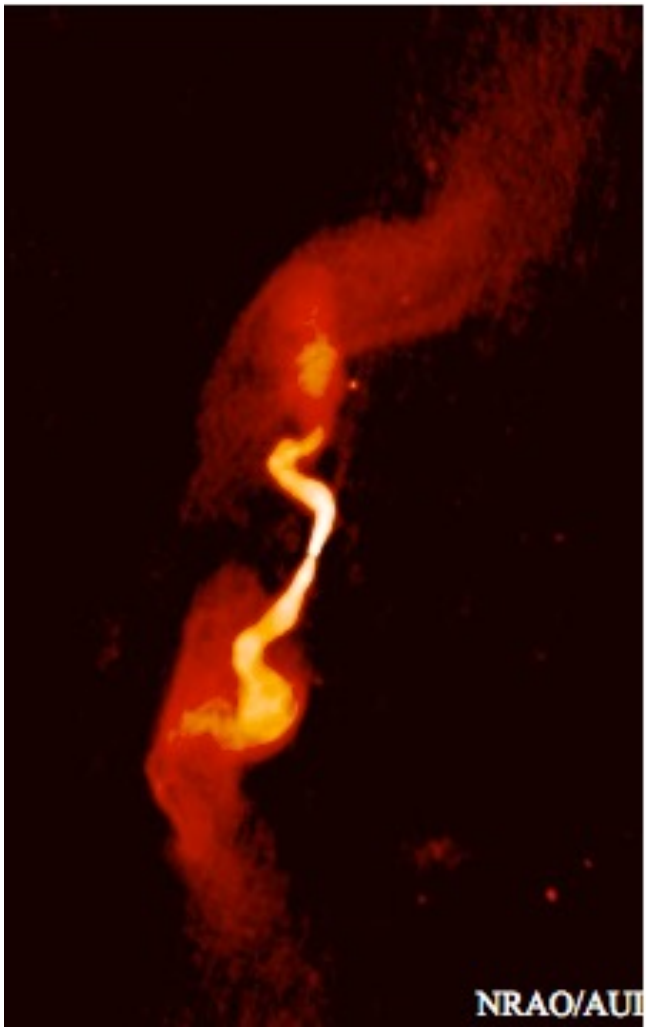
Large radio galaxies with lobes are divided into two types called *Fanaroff-Riley* (1974):

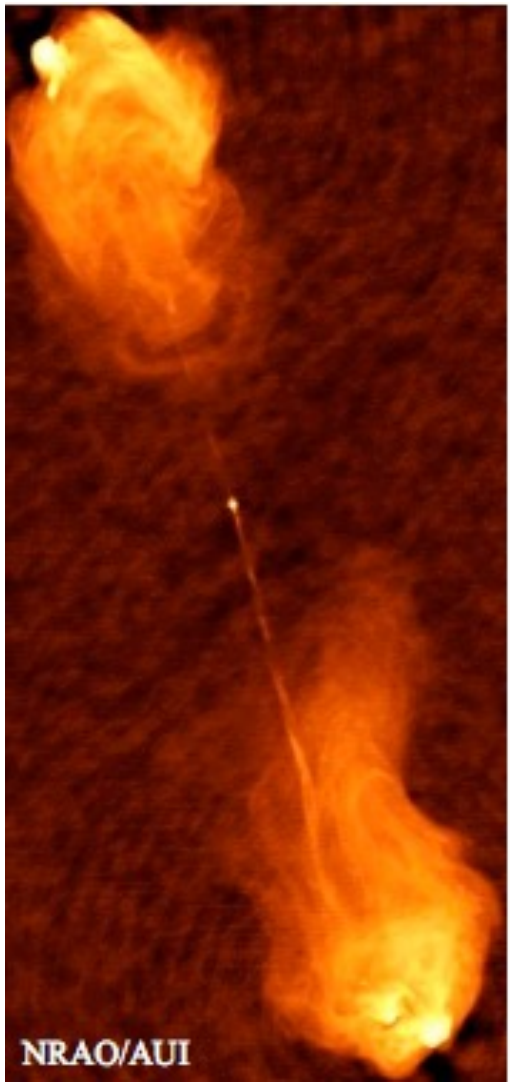
FRI: weaker radio sources that are bright in the center and fainter towards edge of lobes.

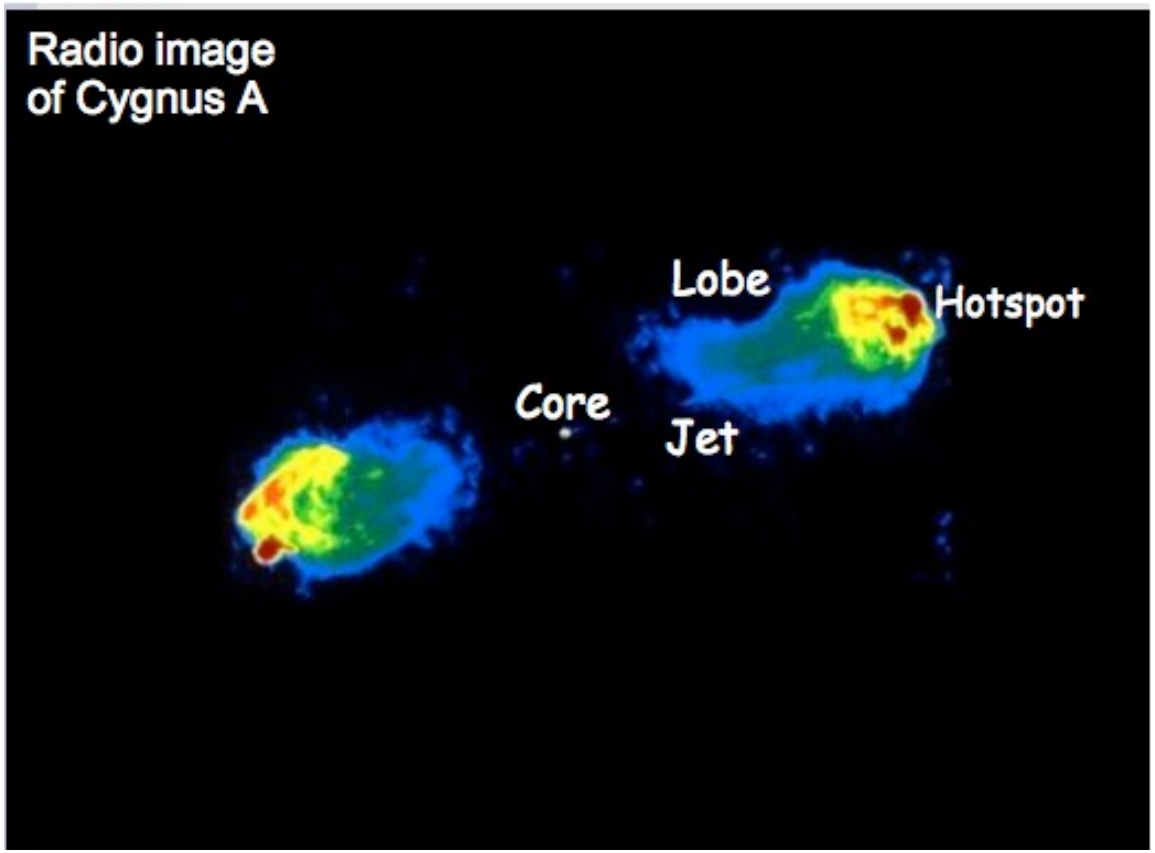
FRII: Brighter radio sources that are brighter towards the limbs.

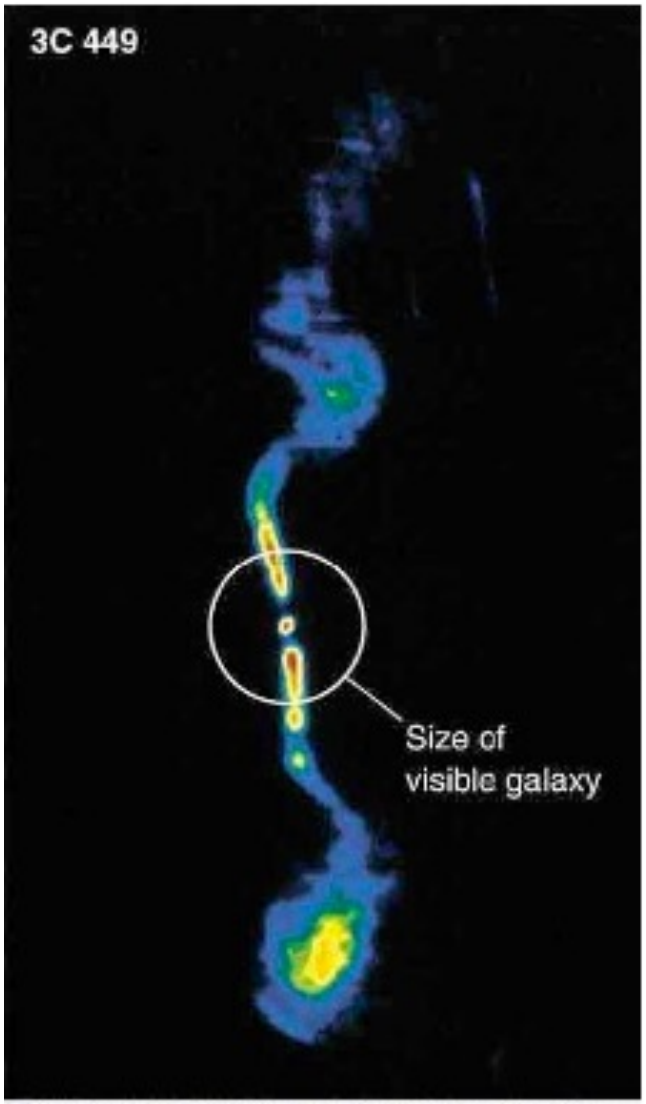
Luminosity transition around $L_{1.4GHz}=10^{25}$ J/s/Hz

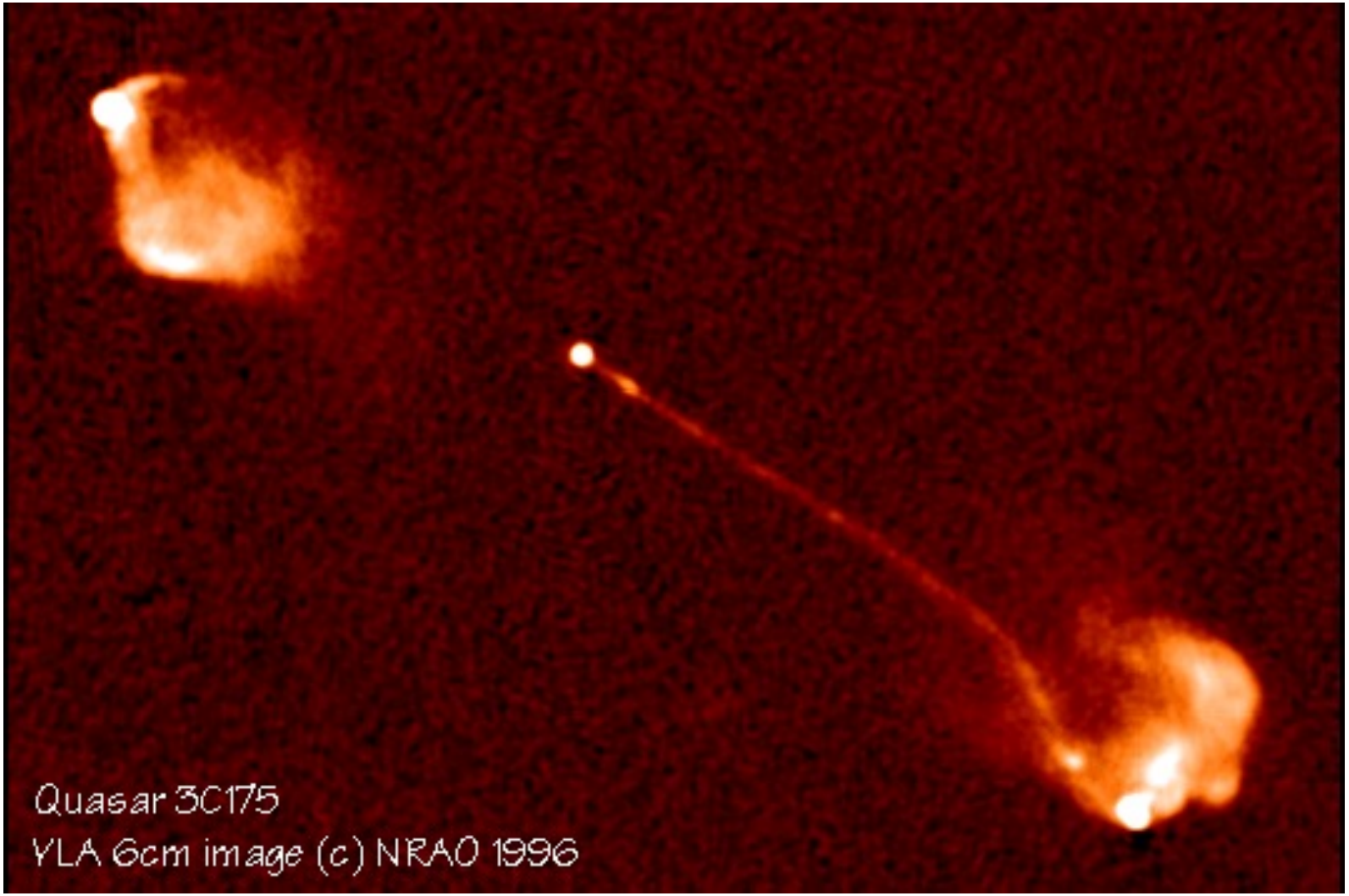
Example FRI and FRII morphologies:

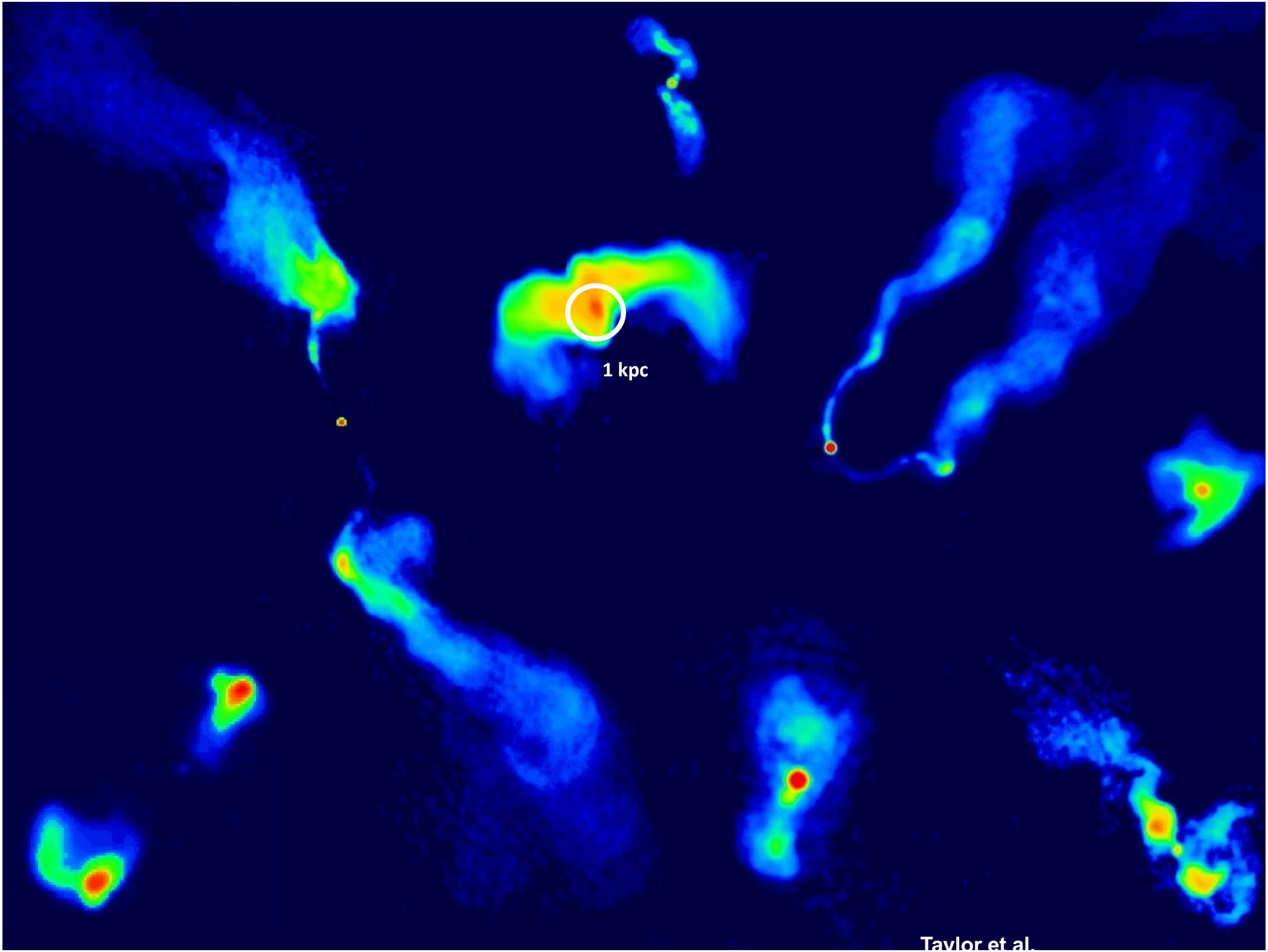


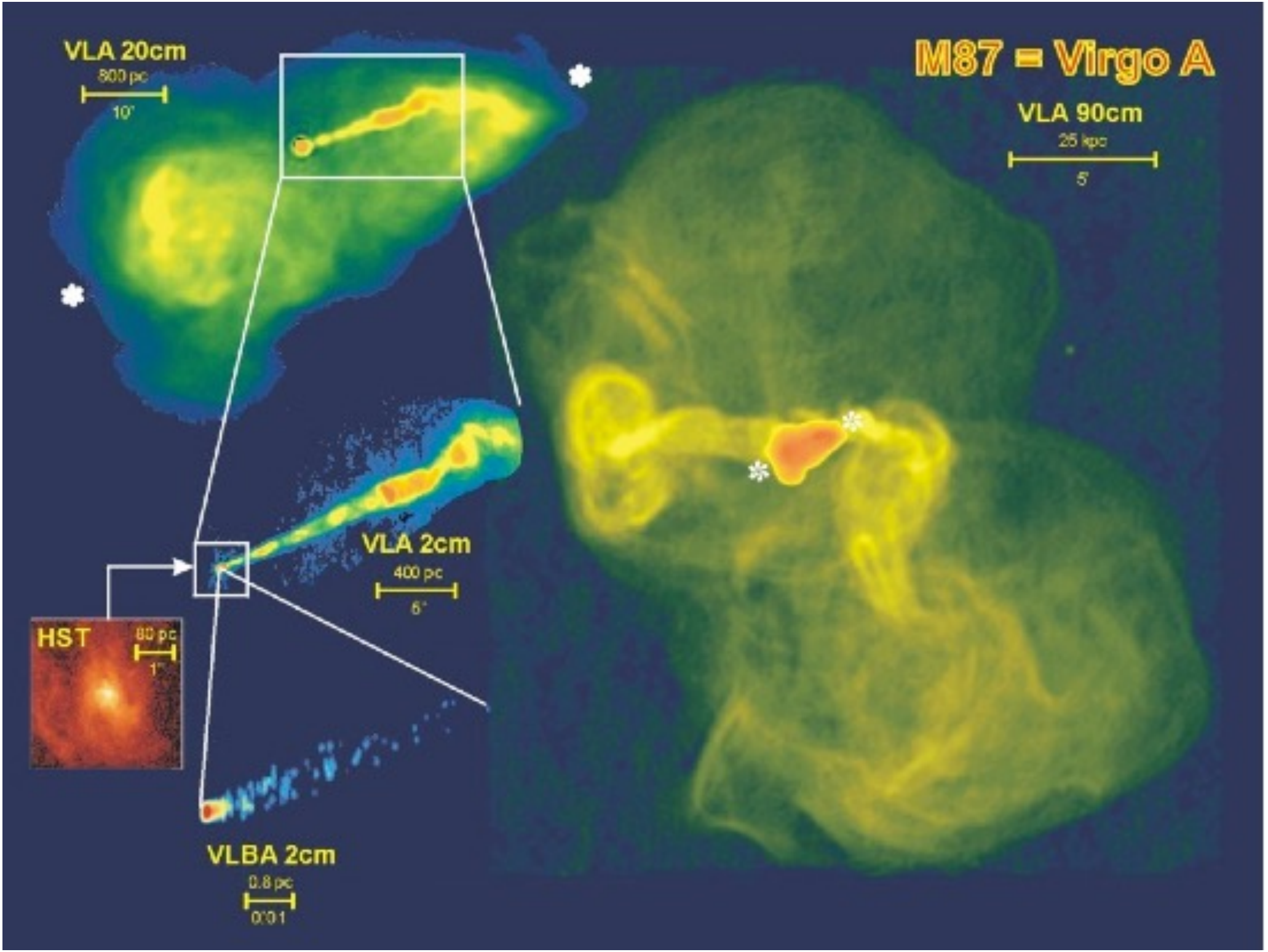


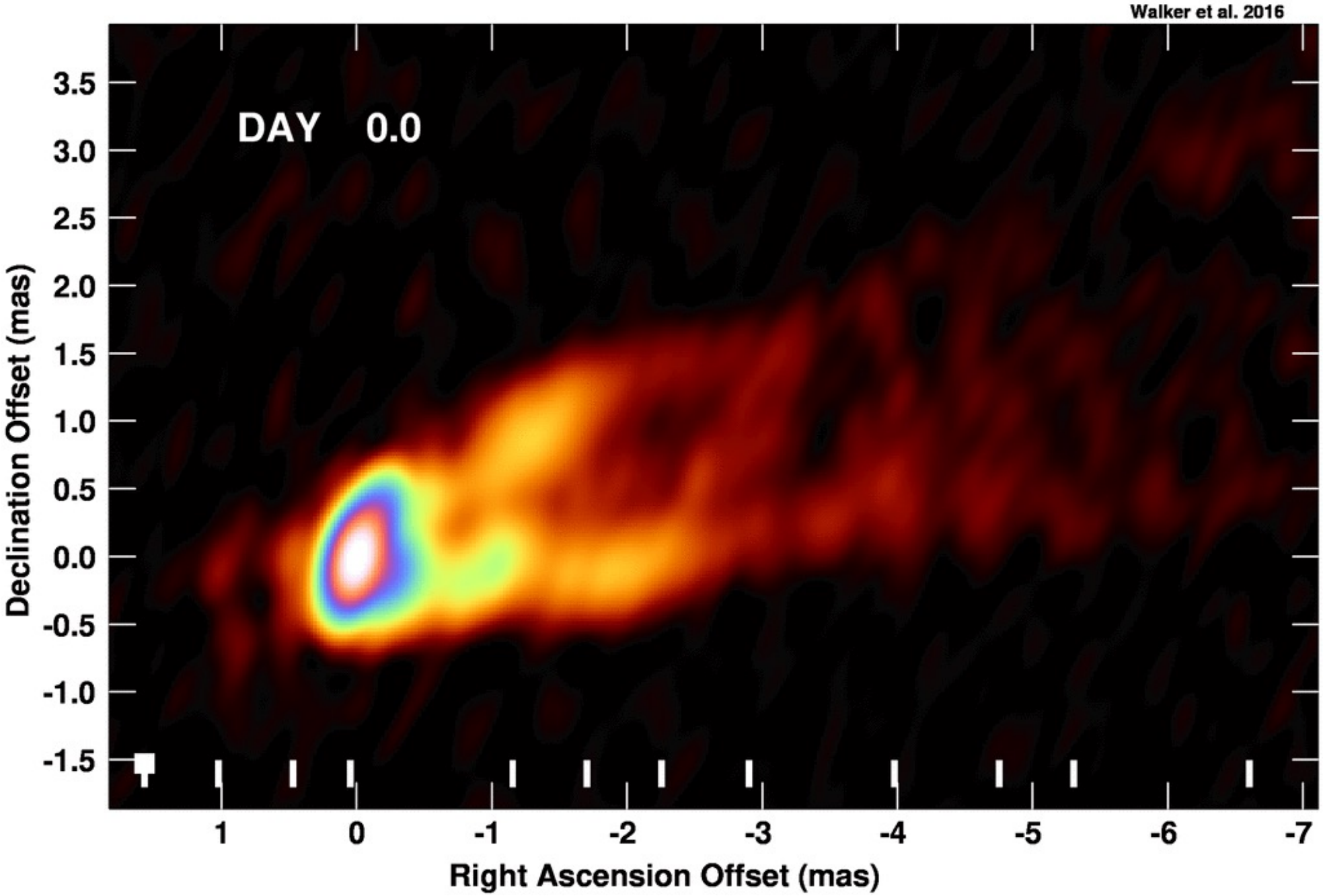




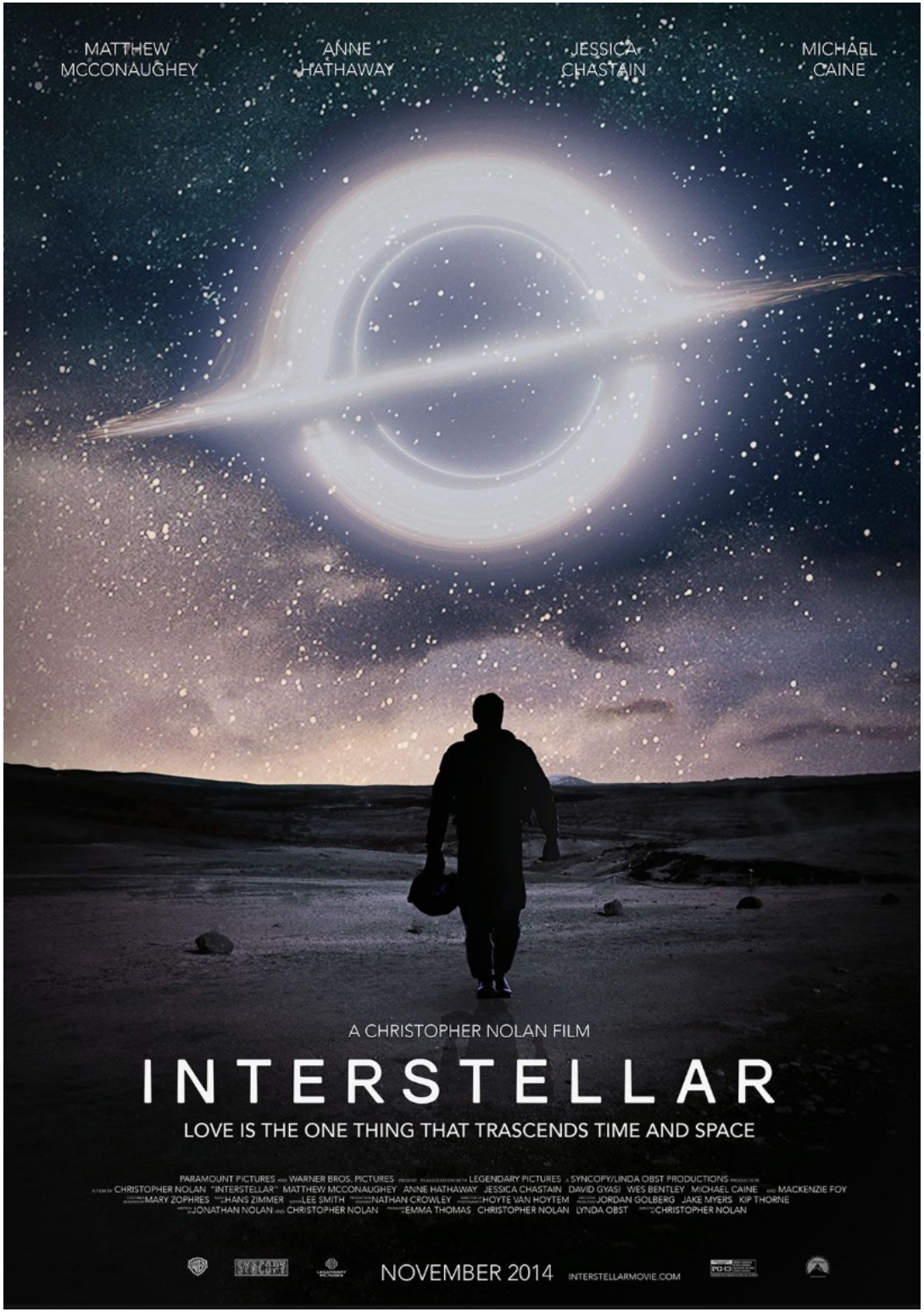

Quasar 3C175
VLA 6cm image (c) NRAO 1996


1 kpc
Taylor et al.


M87 = Virgo A
VLA 20cm
800 pc
10'
VLA 90cm
25 kpc
5'
VLA 2cm
400 pc
6"
HST
80 pc
1"
VLBA 2cm
0.8 pc
0.001



M87 Movie using the VLBA at 43 GHz


MATTHEW MCCONAUGHEY
ANNE HATHAWAY
JESSICA CHASTAIN
MICHAEL CAINE
A CHRISTOPHER NOLAN FILM
INTERSTELLAR
LOVE IS THE ONE THING THAT TRASCENDS TIME AND SPACE
PARAMOUNT PICTURES AND WARNER BROS. PICTURES PRESENT IN ASSOCIATION WITH LEGENDARY PICTURES A SYNCOPY/LINDA OBST PRODUCTIONS PRODUCTION
A FILM BY CHRISTOPHER NOLAN "INTERSTELLAR" MATTHEW MCCONAUGHEY ANNE HATHAWAY JESSICA CHASTAIN DAVID GYASI WES BENTLEY MICHAEL CAINE AND MACKENZIE FOY
CASTING BY MARY ZOPHRES MUSIC BY HANS ZIMMER EDITED BY LEE SMITH PRODUCTION DESIGNER NATHAN CROWLEY DIRECTOR OF PHOTOGRAPHY HOYTE VAN HOYTEM VISUAL EFFECTS BY JORDAN GOLBERG JAKE MYERS KIP THORNE
WRITTEN BY JONATHAN NOLAN AND CHRISTOPHER NOLAN PRODUCED BY EMMA THOMAS CHRISTOPHER NOLAN LYNDA OBST WRITTEN BY CHRISTOPHER NOLAN
NOVEMBER 2014
INTERSTELLARMOVIE.COM
PG-13

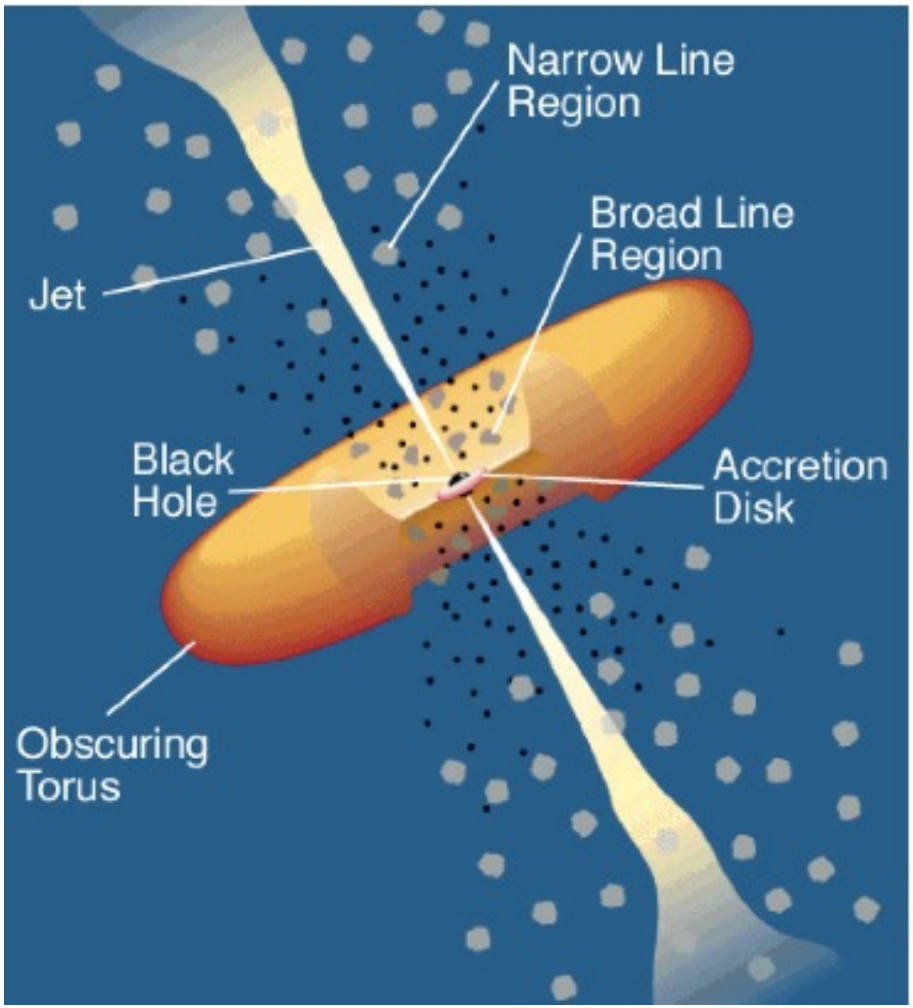
Journal Class

- **First M87 Event Horizon Telescope Results. I. The Shadow of the Supermassive Black Hole**
- The EHT Collaboration 2019

Discussion leader: **Mark Burch**

Note: To encourage discussion everybody must pose at least one question during the group discussion

Astronomy 537



Lecture 20: Active Galactic Nuclei II

Key concepts:

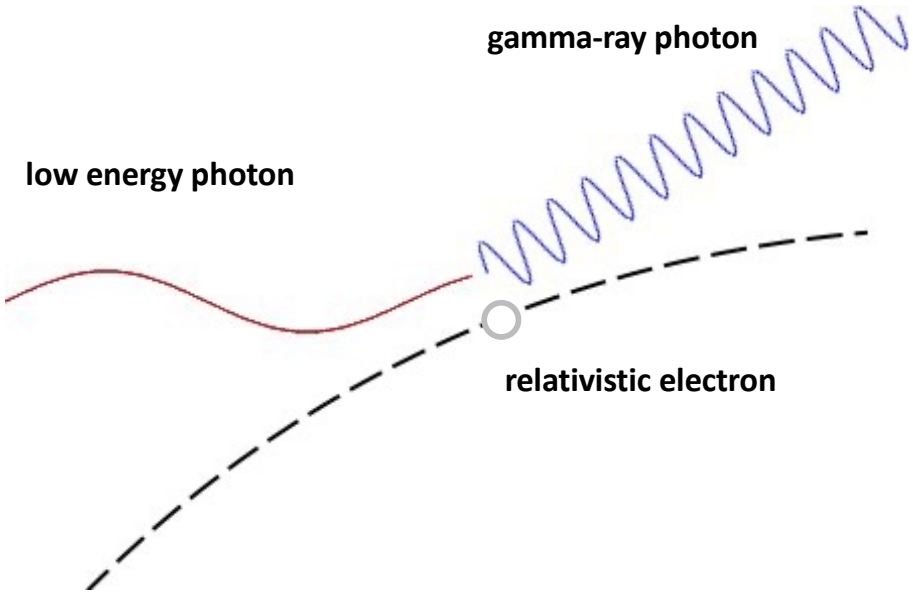
Spectral Energy Distributions

Unified scheme

Superluminal motion

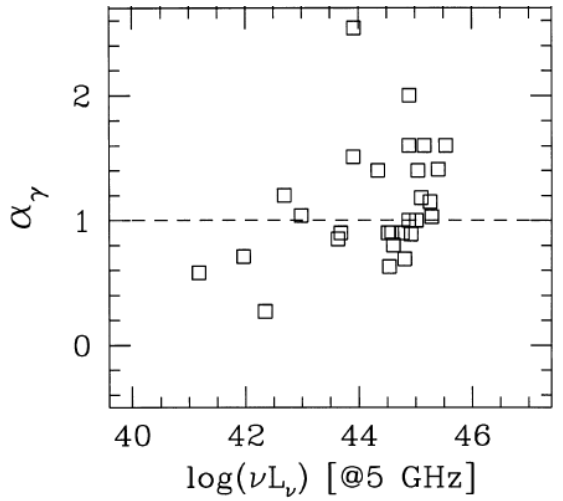
Inverse Compton Scattering in AGN

- synchrotron radio emission originates from relativistic electrons that can upscatter photons to high energy
  - some connection between radio and gamma-ray properties is expected!
  - observationally, all gamma-ray AGNs are radio loud, unlike most X-ray QSOs

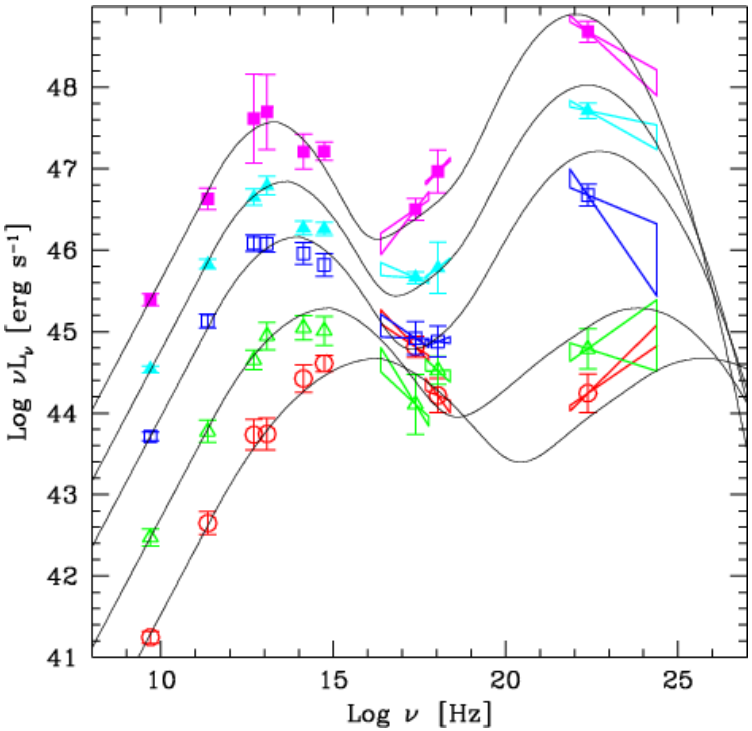


Background

- the blazar sequence was originally devised on the basis of the radio luminosity
- See Muecke et al. etc



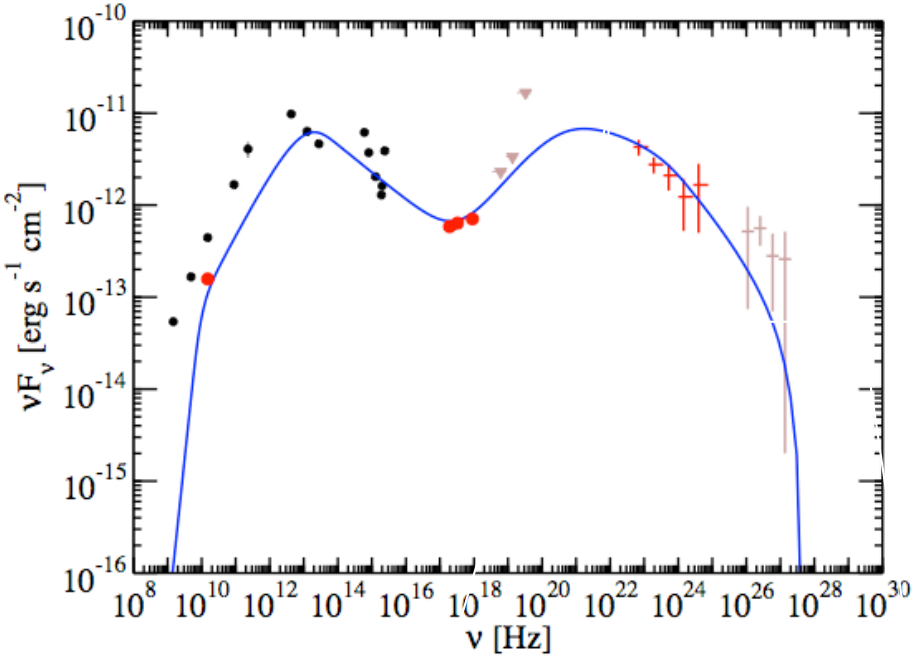
Fossati et al. (1998)

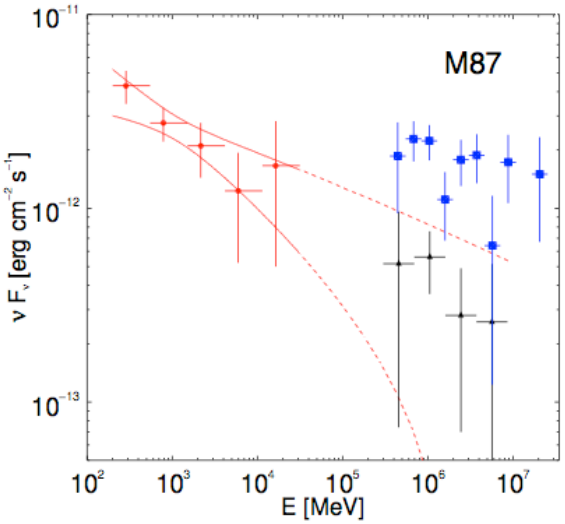


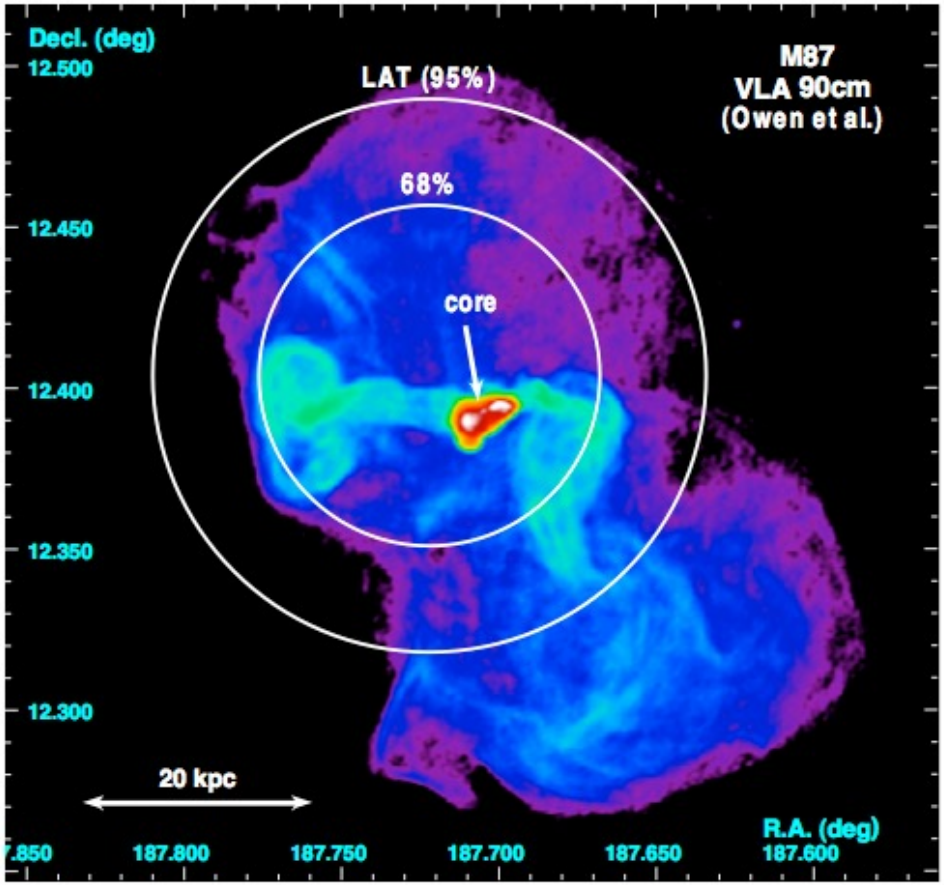
Donato et al. (2001)

Fermi Gamma-ray Space Telescope

M87







Abdo et al. (2009)