



ASTRONOMIA

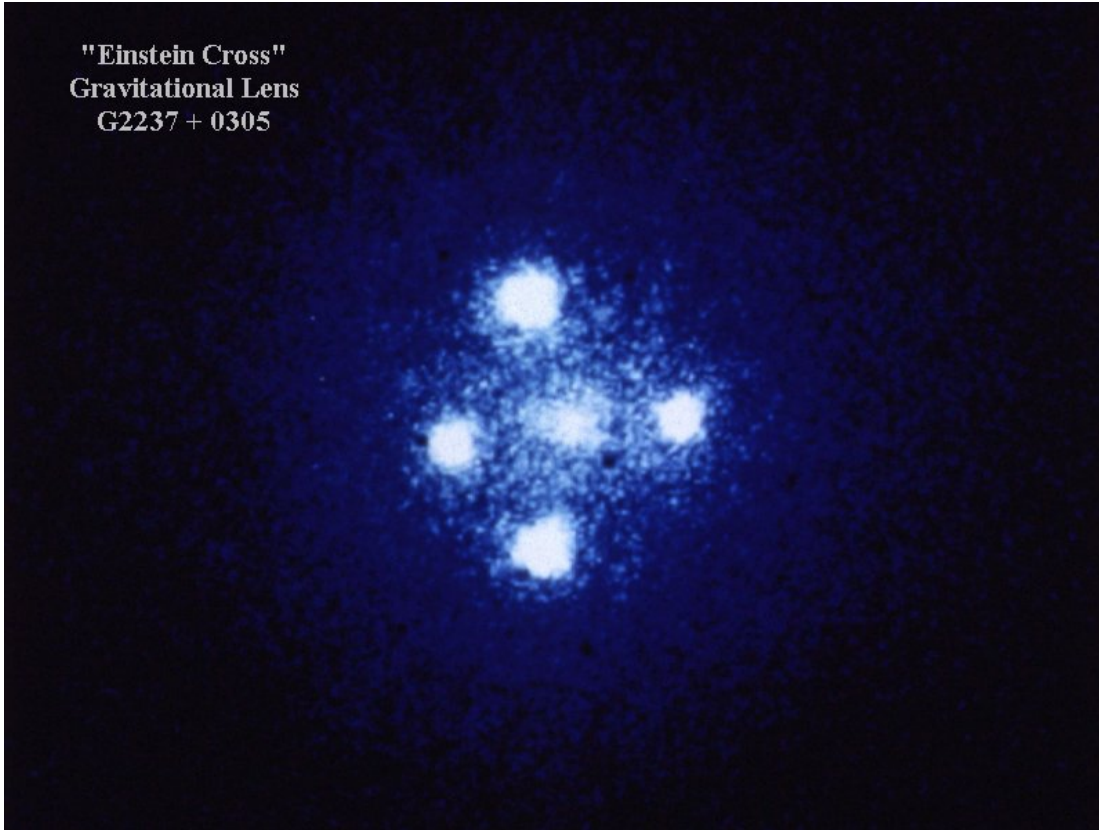
Relativitat: Escenaris Astrofísics II: L'Univers

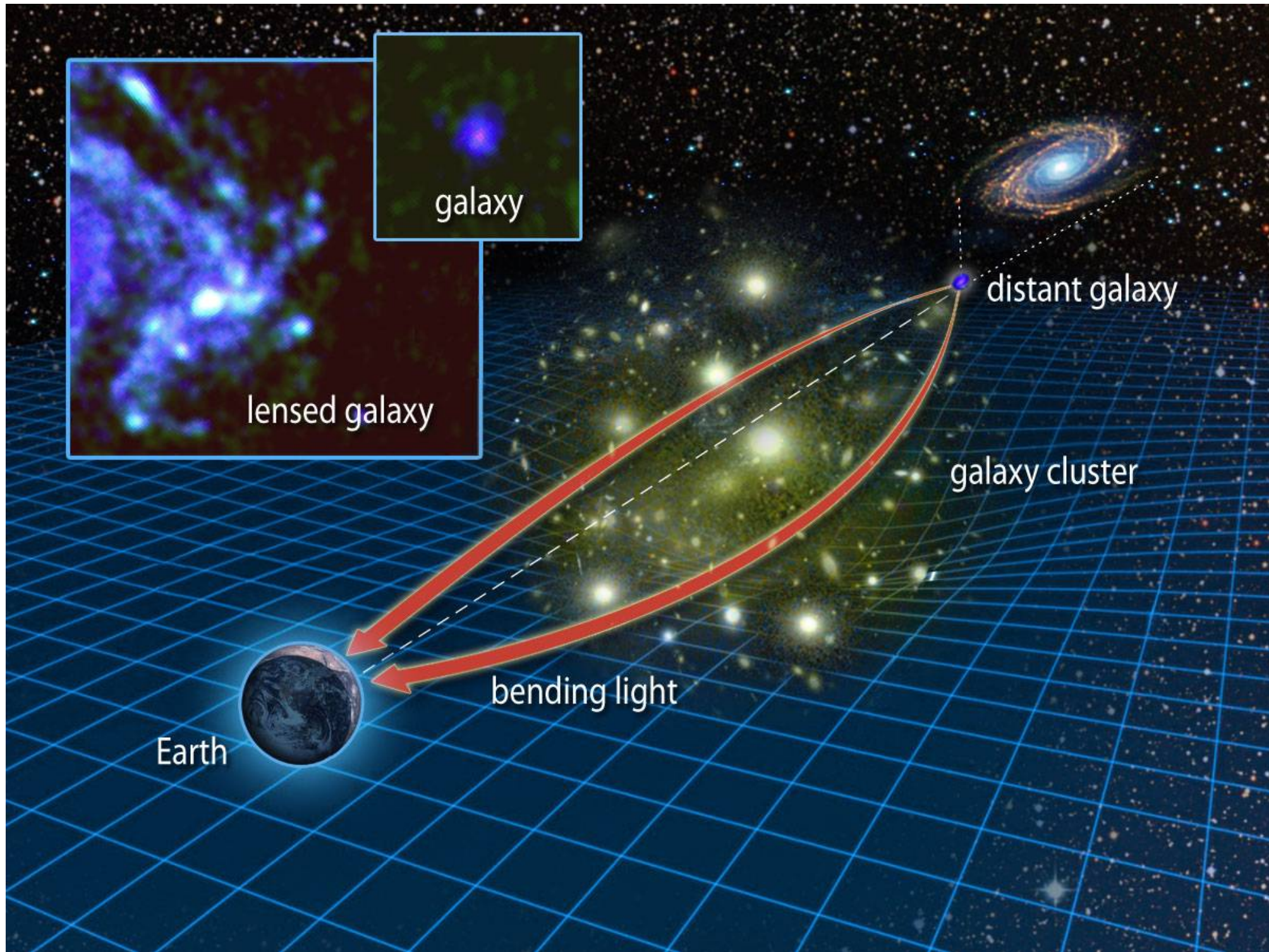
La Nau Gran

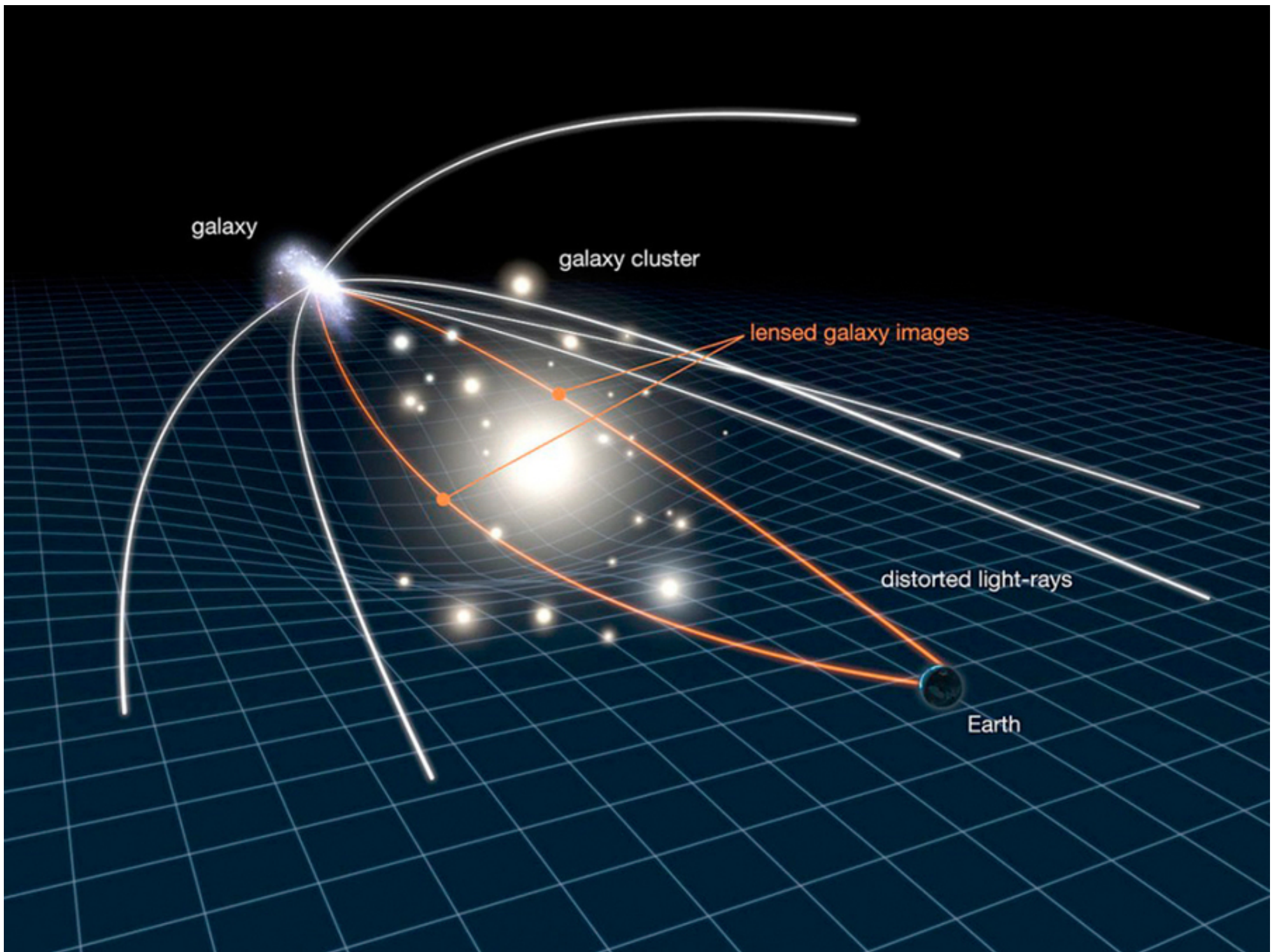
Manel Perucho

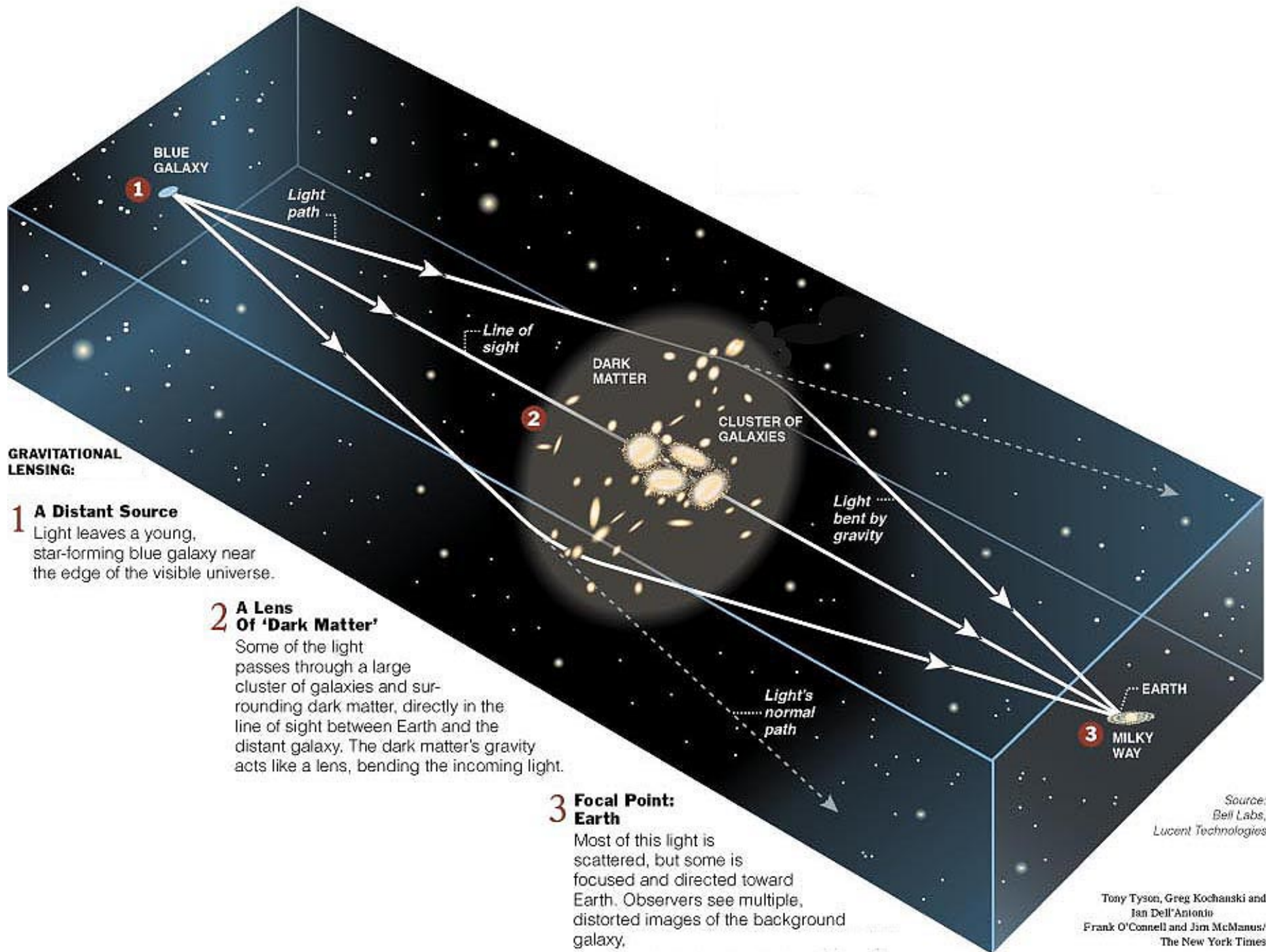
Lents gravitatoris

"Einstein Cross"
Gravitational Lens
G2237 + 0305









GRAVITATIONAL LENSING:

1 A Distant Source

Light leaves a young, star-forming blue galaxy near the edge of the visible universe.

2 A Lens Of 'Dark Matter'

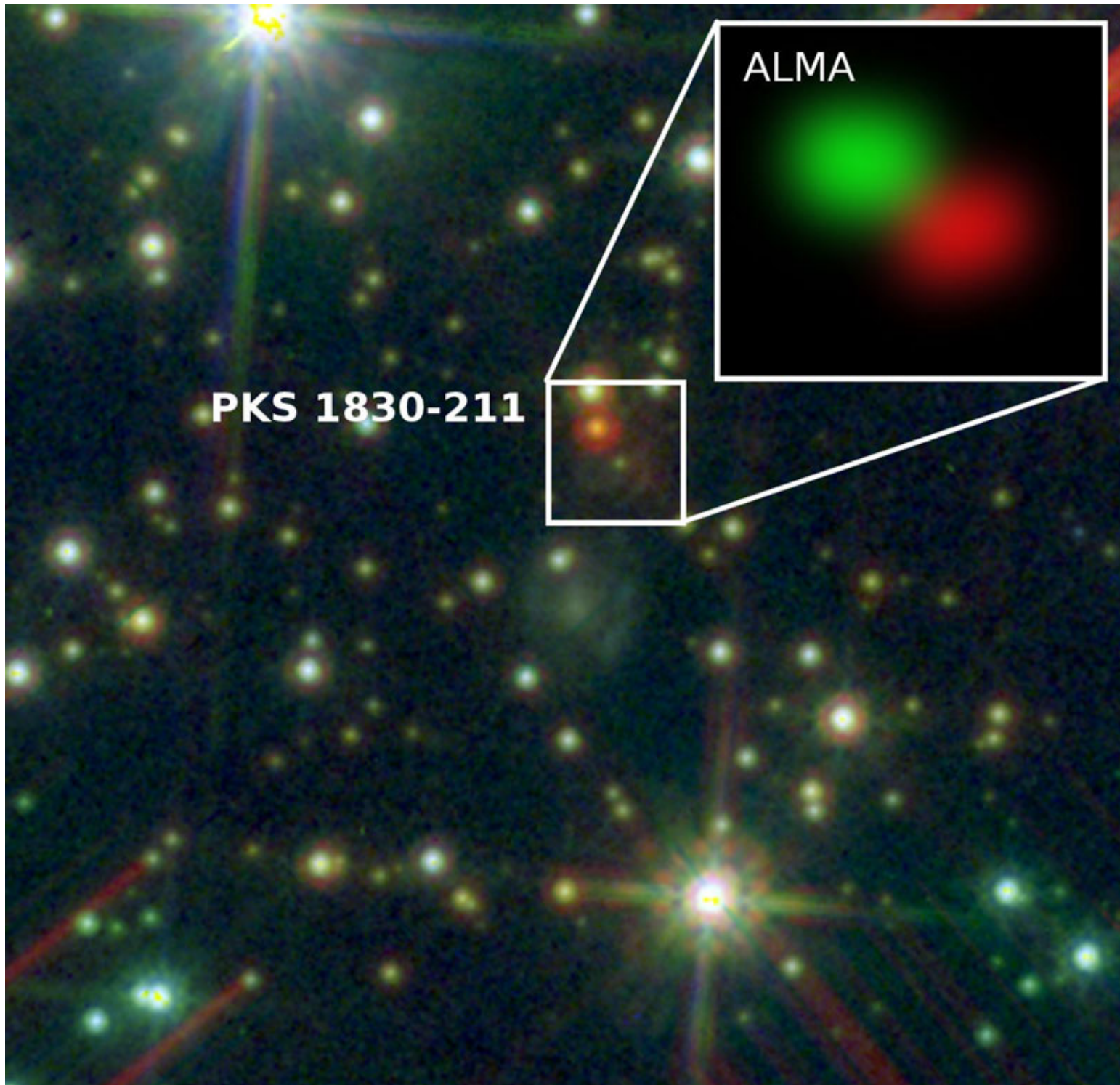
Some of the light passes through a large cluster of galaxies and surrounding dark matter, directly in the line of sight between Earth and the distant galaxy. The dark matter's gravity acts like a lens, bending the incoming light.

3 Focal Point: Earth

Most of this light is scattered, but some is focused and directed toward Earth. Observers see multiple, distorted images of the background galaxy.

Source:
Bell Labs,
Lucent Technologies

Tony Tyson, Greg Kochanski and
Jan Dell'Antonio
Frank O'Connell and Jim McManus/
The New York Times



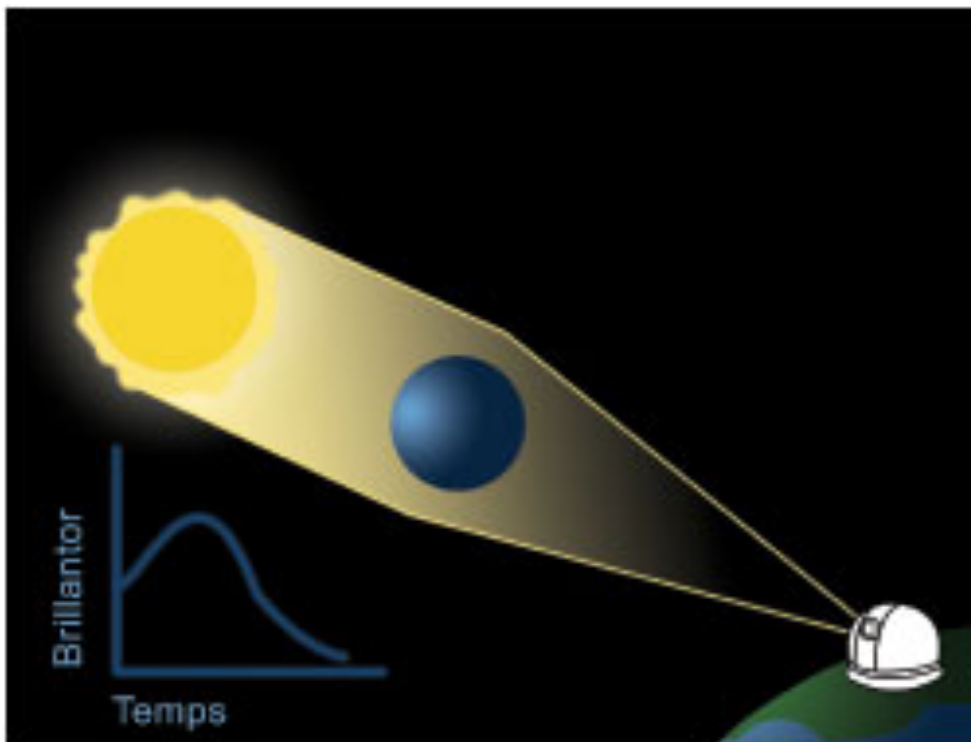
PKS 1830-211

ALMA

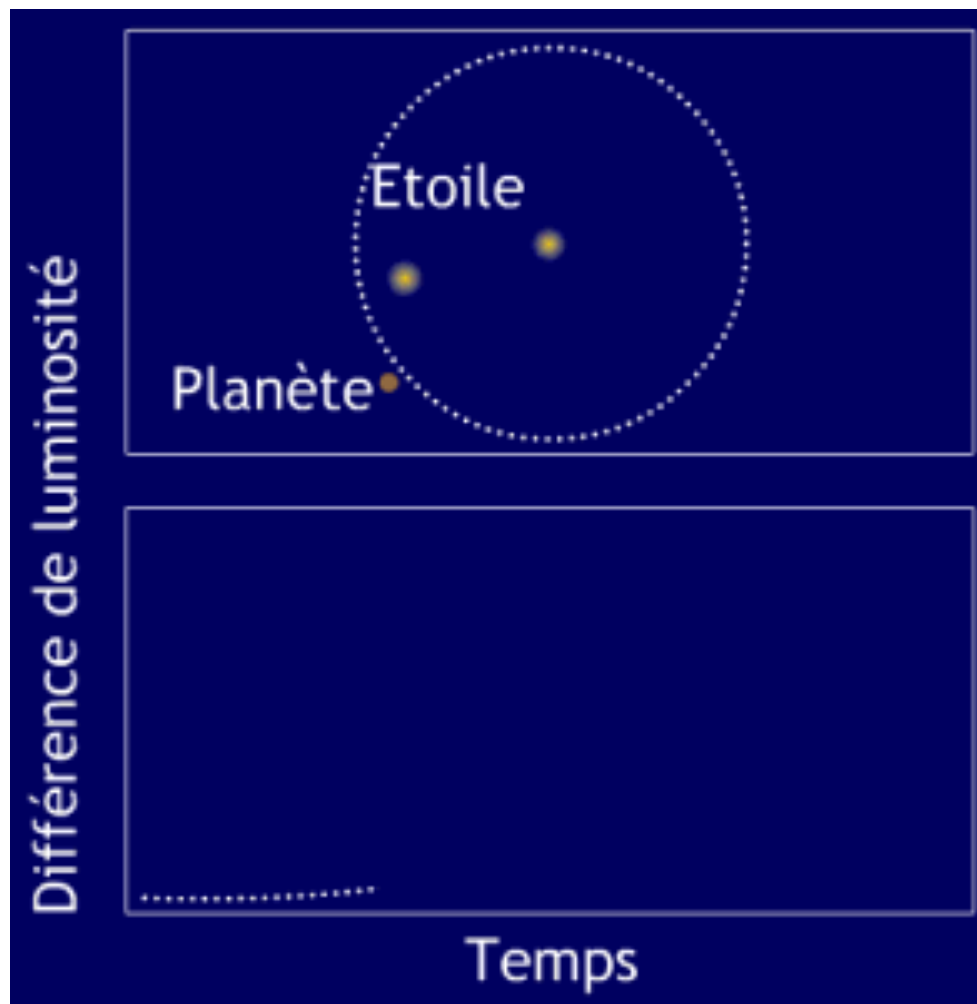
Martí-Vidal
et al.

Exoplanetes

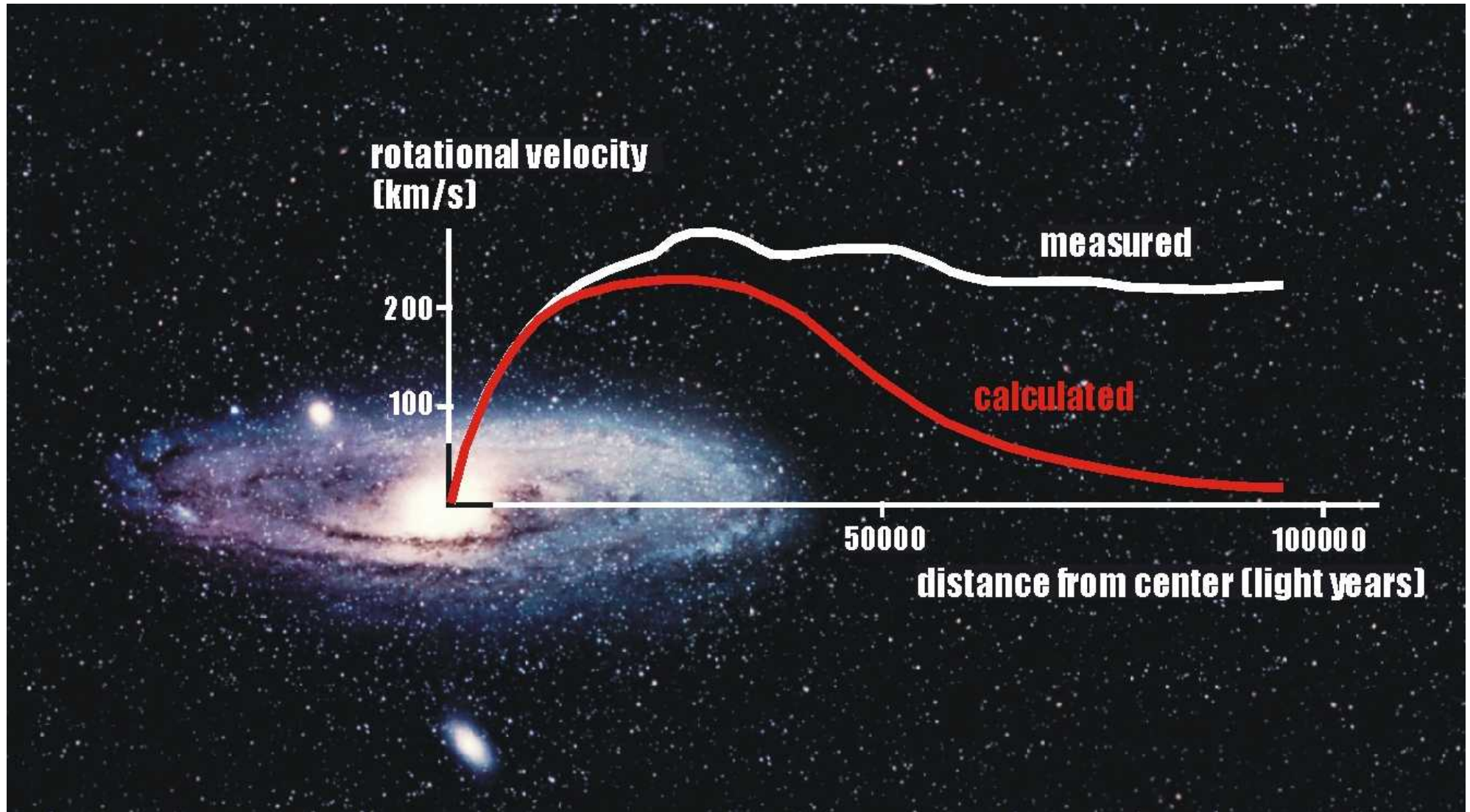
Efecte microlent



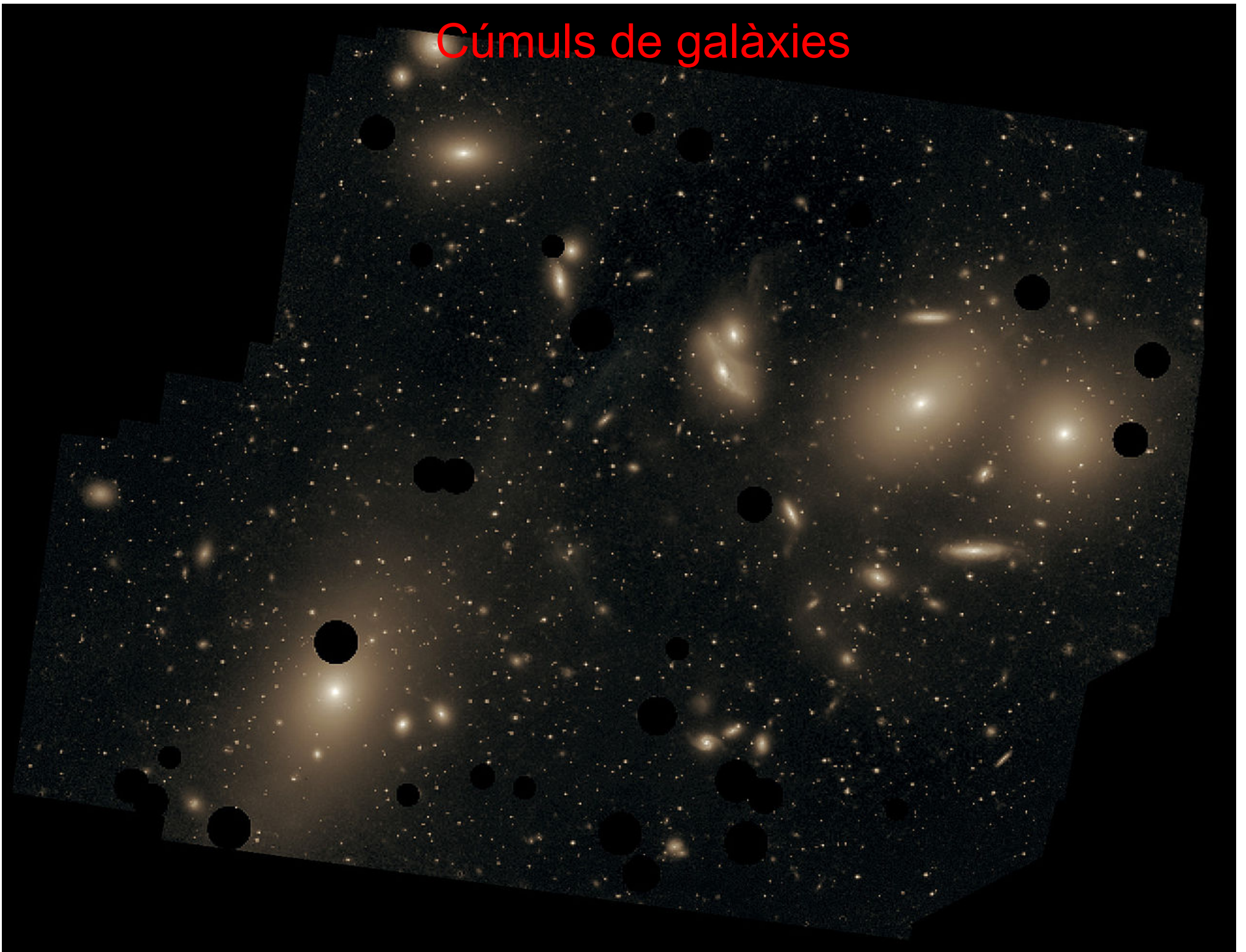
Mètodes de detecció



Matèria fosca



Cúmuls de galàxies



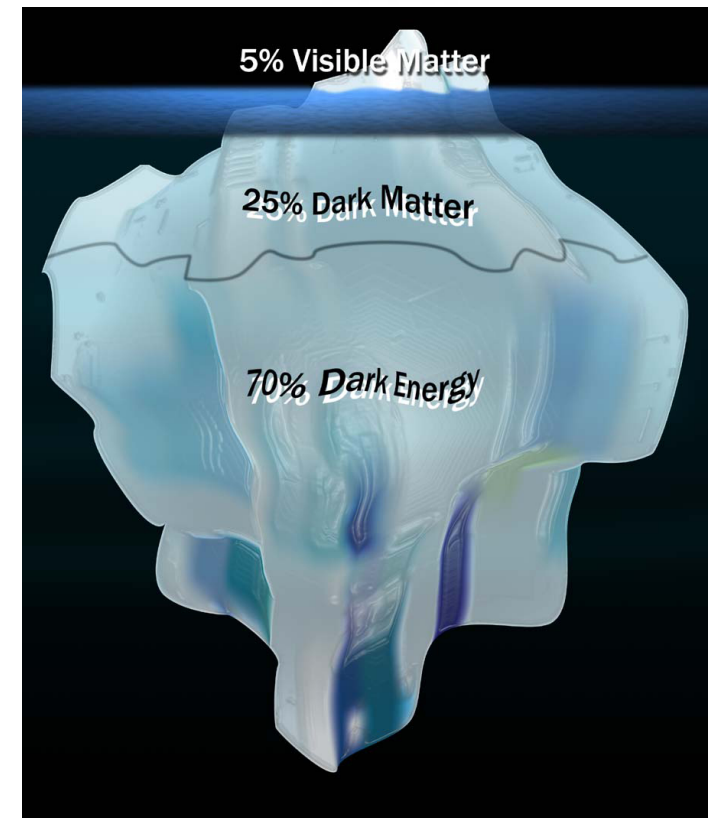
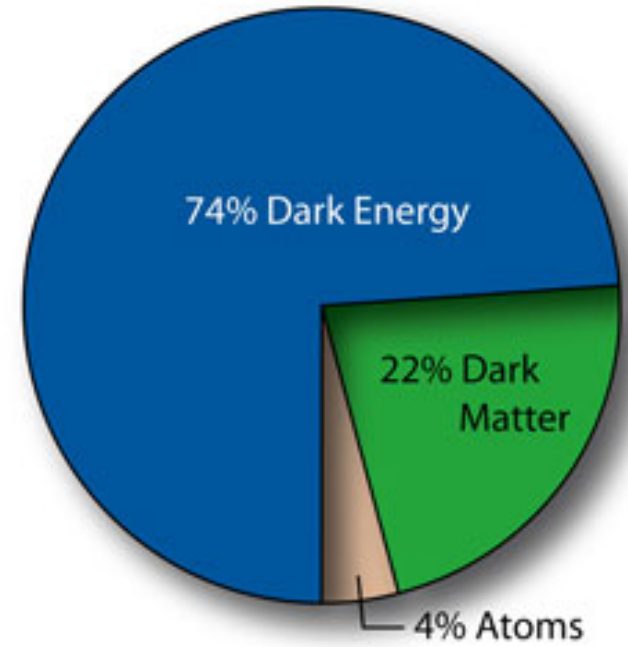
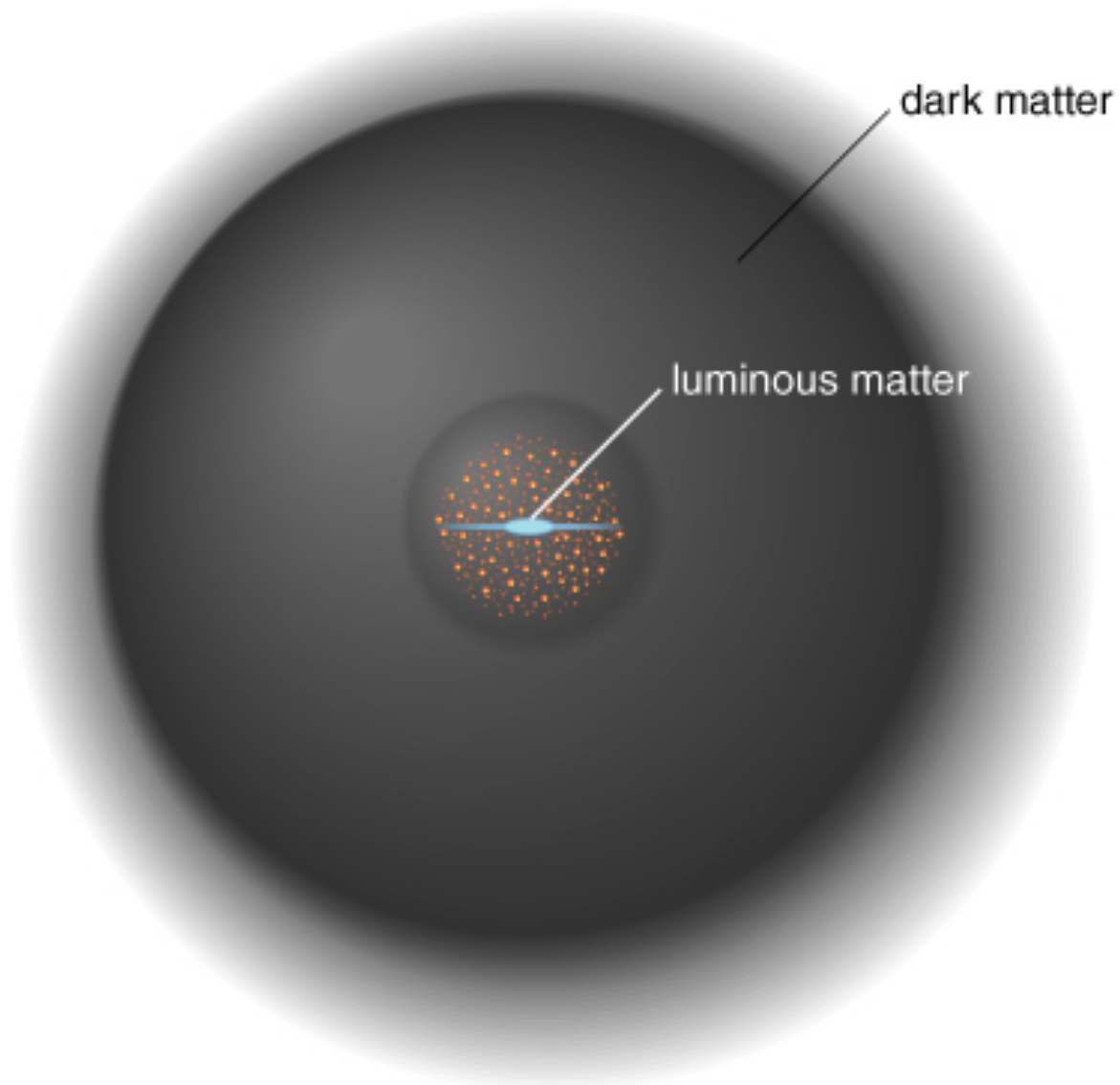
Cúmuls de galàxies



Matèria fosca

- La corba de rotació de les galàxies indica que cal més massa que la visible per explicar-les.
- Les galàxies que formen un cúmul i els gas que s'hi troba entre elles no poden estar lligats gravitacionalment sense la presència de més matèria, invisible.

Matèria fosca





Galaxies Actives

Galaxies Actives

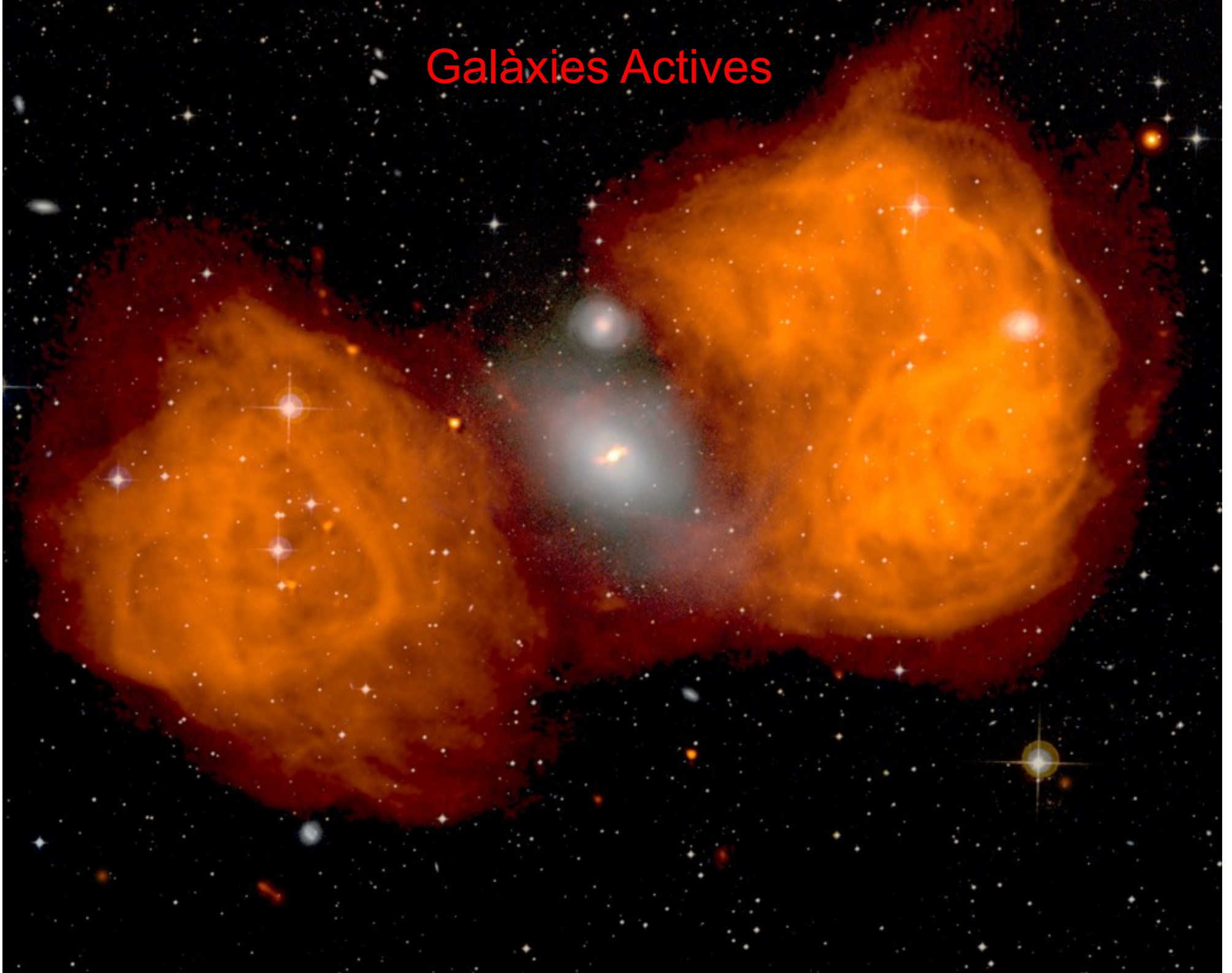
3C 273 - quasar



M87 - radiogalàxia



Galaxies Actives

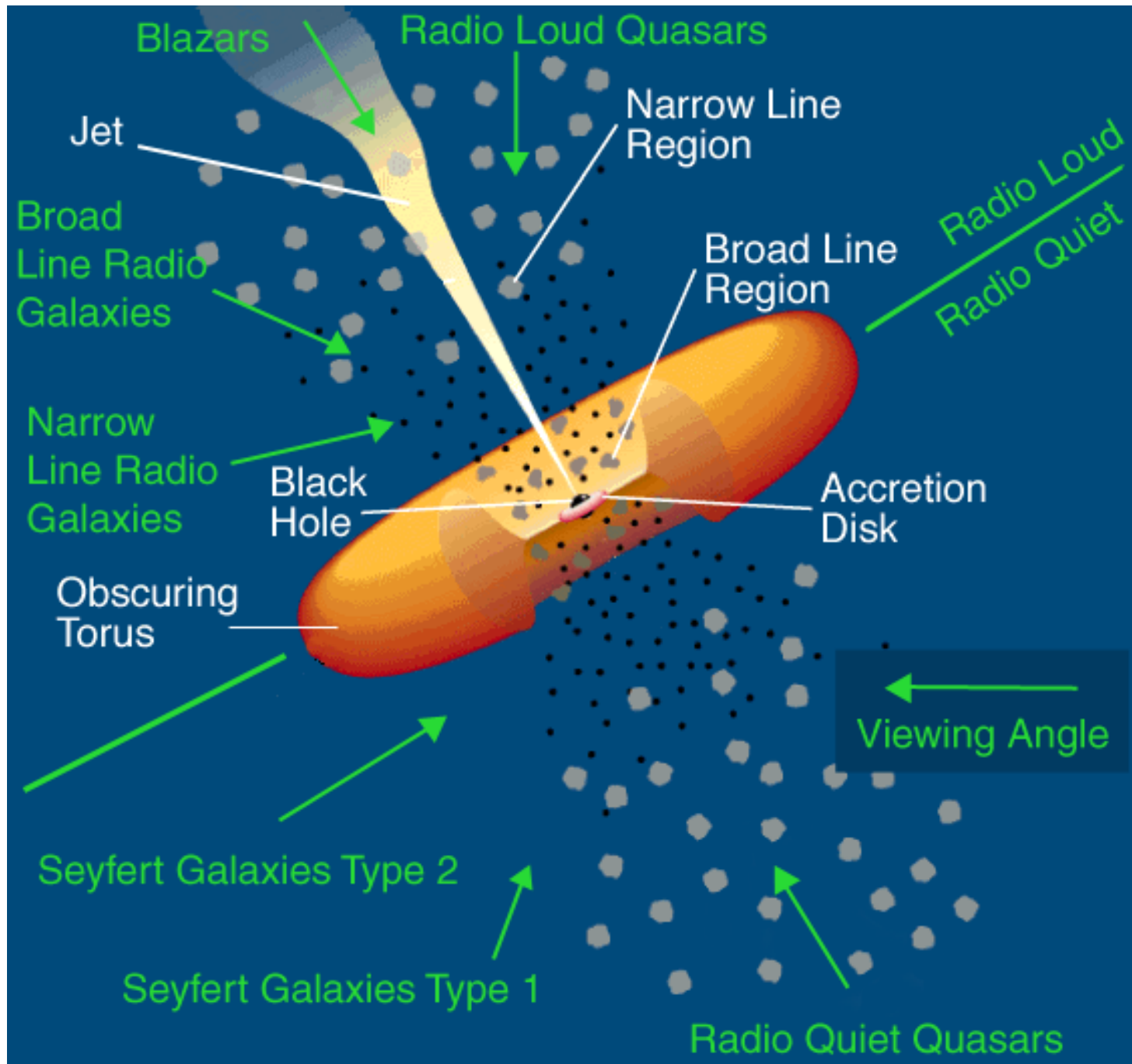


Galaxies Actives





Previous concepts (in short)



extragalactic jets – the standard model

The **production of jets** is connected with the process of accretion on supermassive black holes at the core of AGNs

- **Hydromagnetic acceleration** (Blandford-Payne)
- **Extraction of rotational energy from Kerr BH** by magnetic processes (Blandford-Znajek, Penrose)

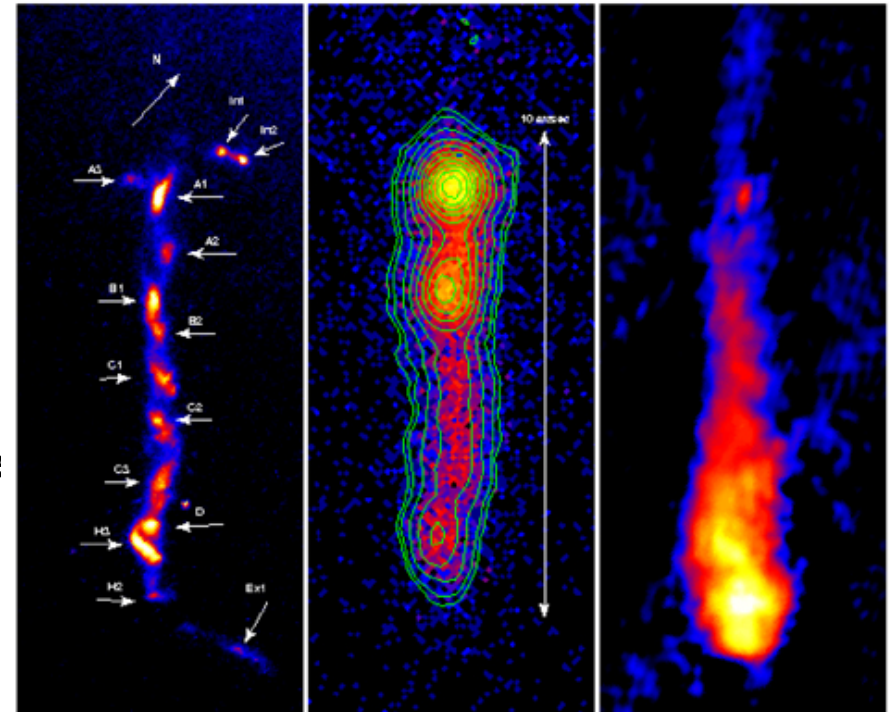
Emission: synchrotron (from radio to X-rays) and **inverse Compton** (γ -ray emission) from a relativistic (e^+/e^- , ep) jet (e.g., Ghisellini et al. 1998). Seed photons for the IC process:

- Self Compton: synchrotron photons
- External Compton: disk, BLR, dusty torus, CMB

Jets are **relativistic**, as indicated by:

- Superluminal motion at pc scales.
- One-sidedness of pc scale jets and brightness asymmetries between jets and counterjets at kpc scales (due to Doppler boosting of the emitted radiation).

3C273 HST – CHANDRA - MERLIN

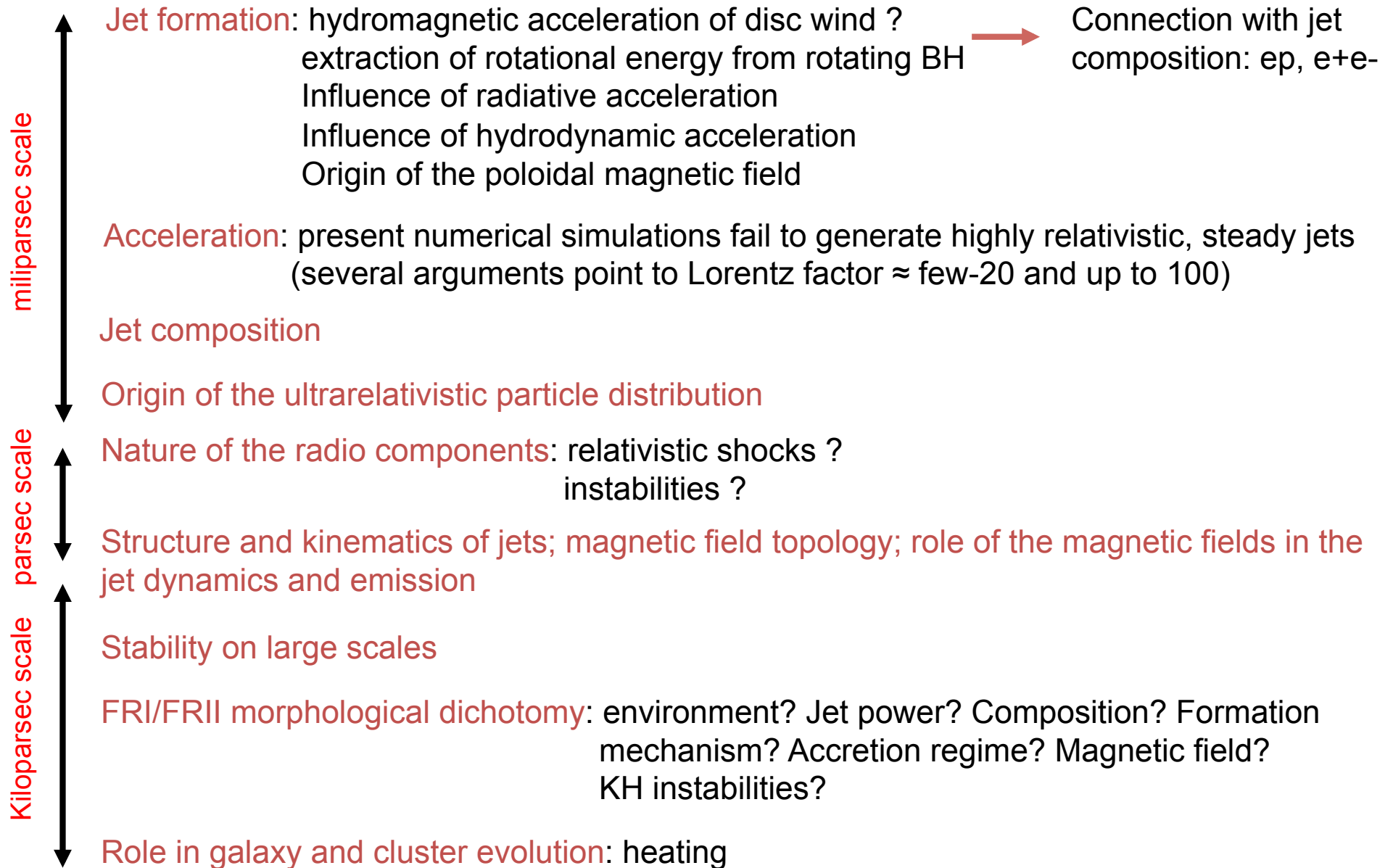


Jets: Relativistic collimated ejections of thermal (e^+/e^- , ep) plasma + ultrarelativistic electrons/positrons + magnetic fields + radiation, generated in the vicinity of SMBH

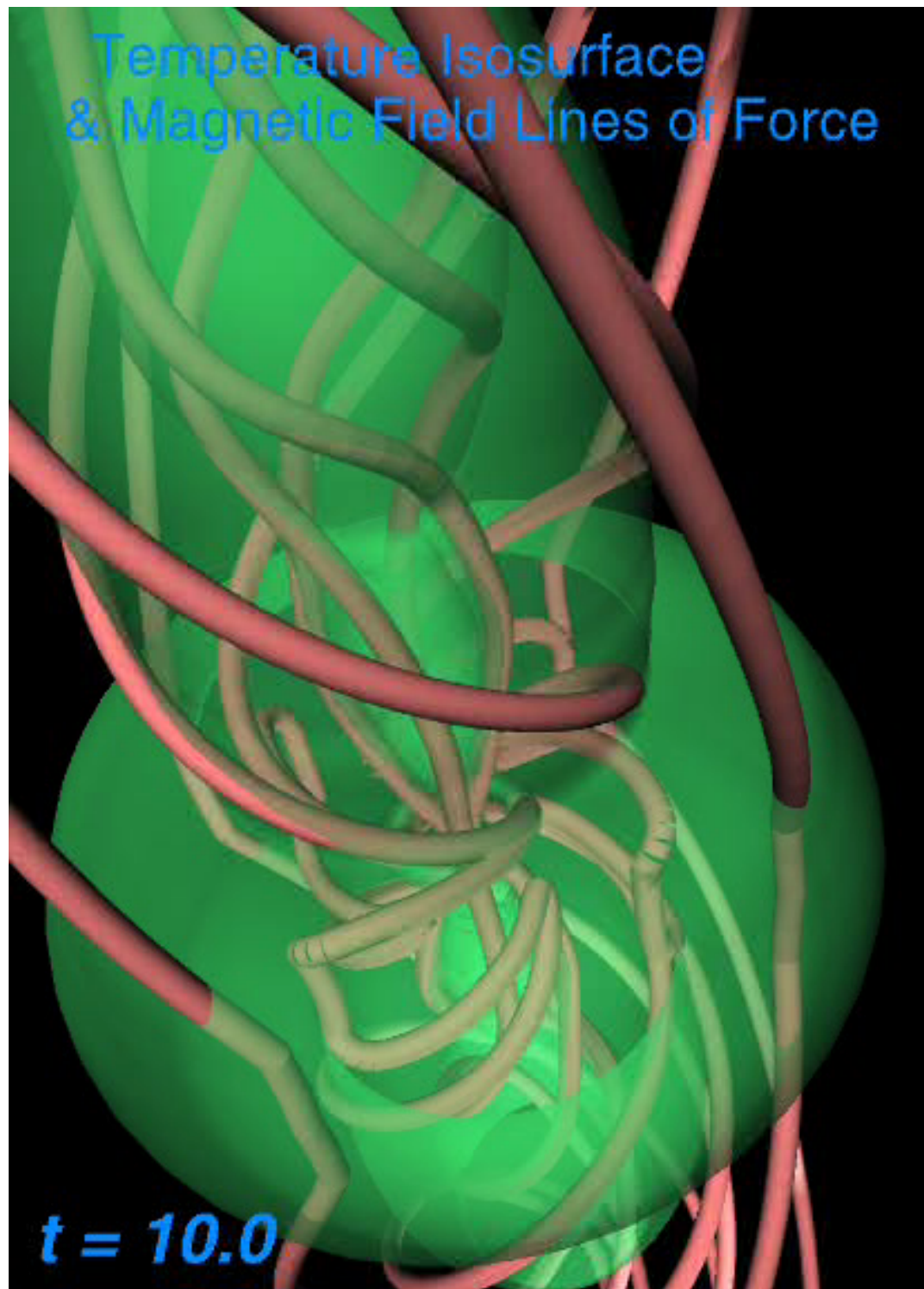


(GENERAL) RELATIVISTIC MHD + ELECTRON TRANSPORT + RADIATION TRANSFER

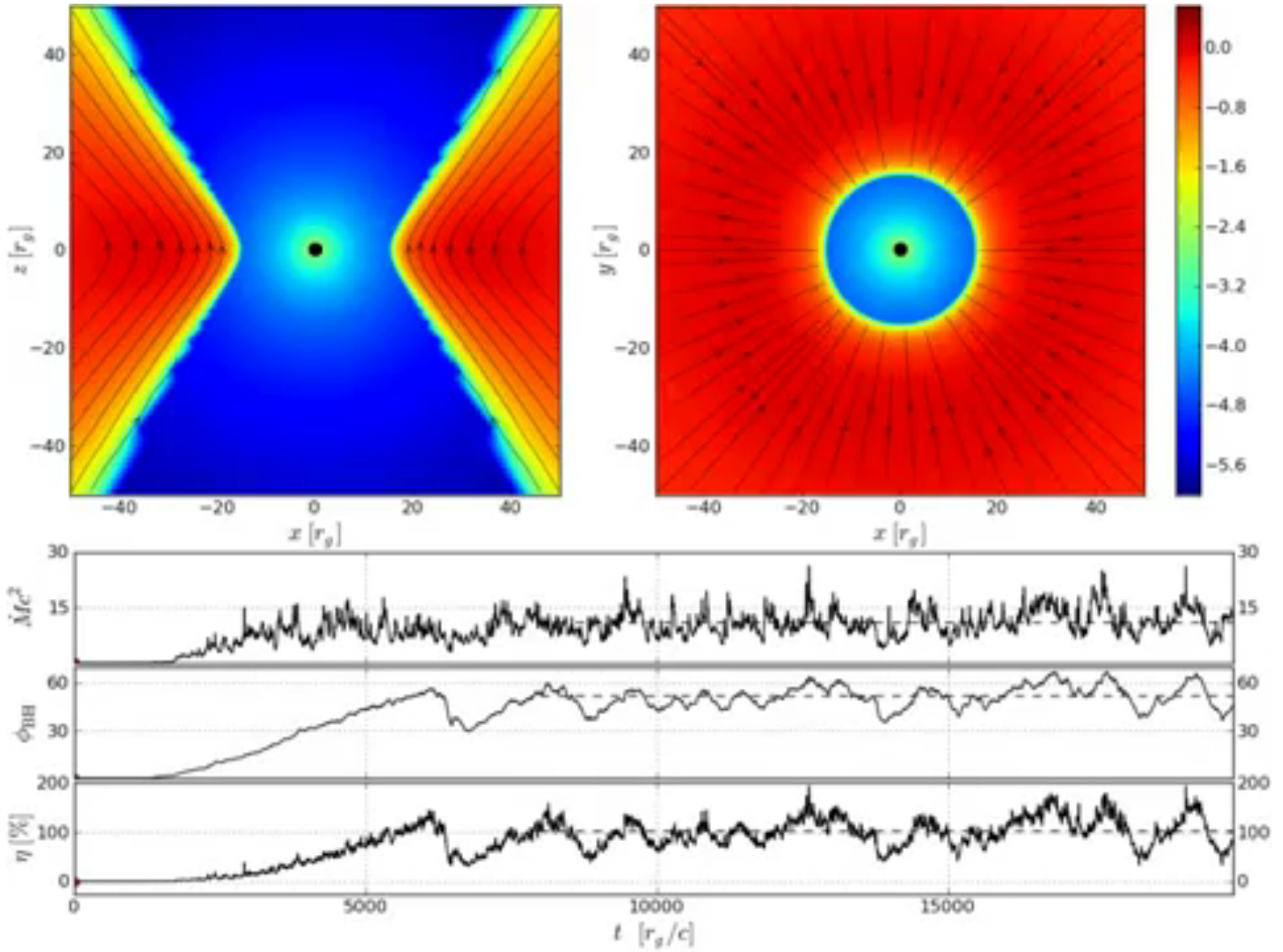
extragalactic jets – open questions



Temperature Isosurface
& Magnetic Field Lines of Force

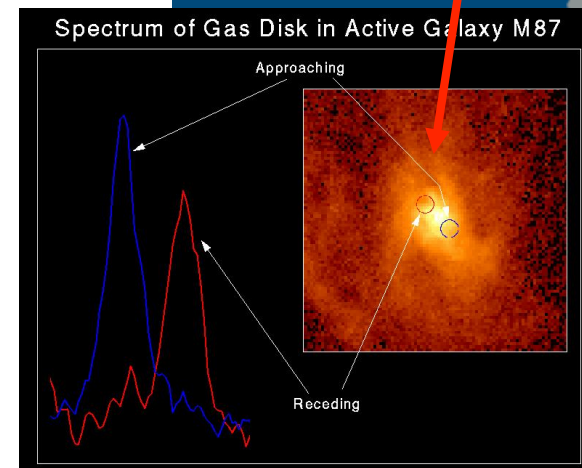
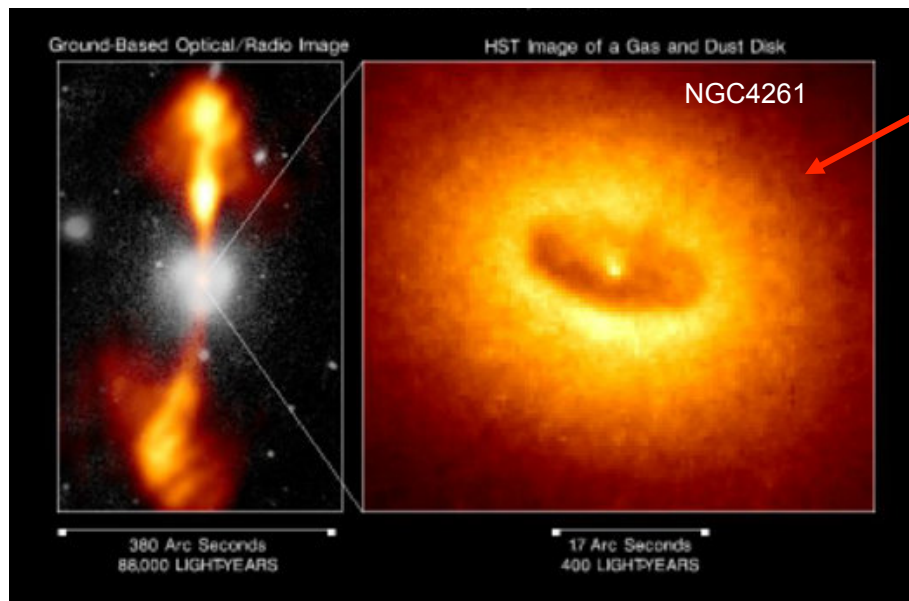
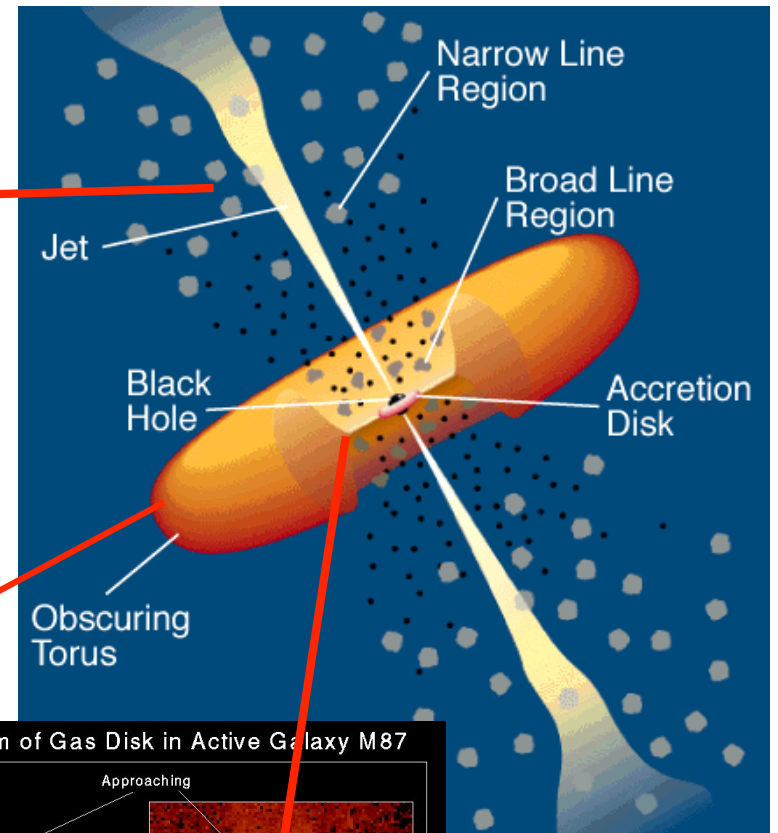
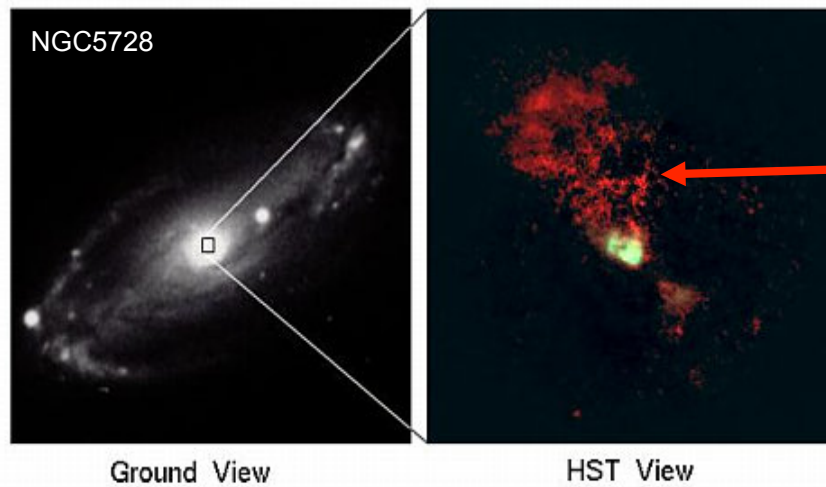


$t = 10.0$



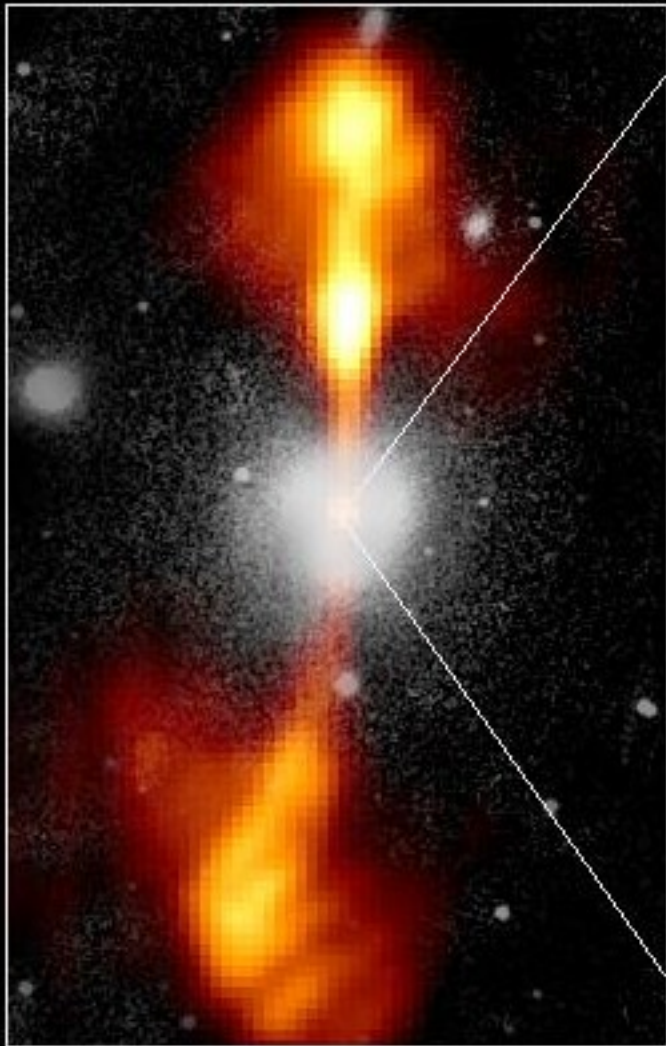
Tchekhovskoy et al.

extragalactic jets – the standard model of AGN



Galaxies Actives

Ground-Based Optical/Radio Image



380 Arc Seconds
88,000 LIGHT-YEARS

HST Image of a Gas and Dust Disk



17 Arc Seconds
400 LIGHT-YEARS

extragalactic jets – radio observations

Jets are a **common ingredient of radio-loud AGNs** detected and imaged at very different spatial scales with different radio interferometry arrays (kpc scales: VLA, Merlin; pc scales: VLBA, EVN, Global VLBI...).

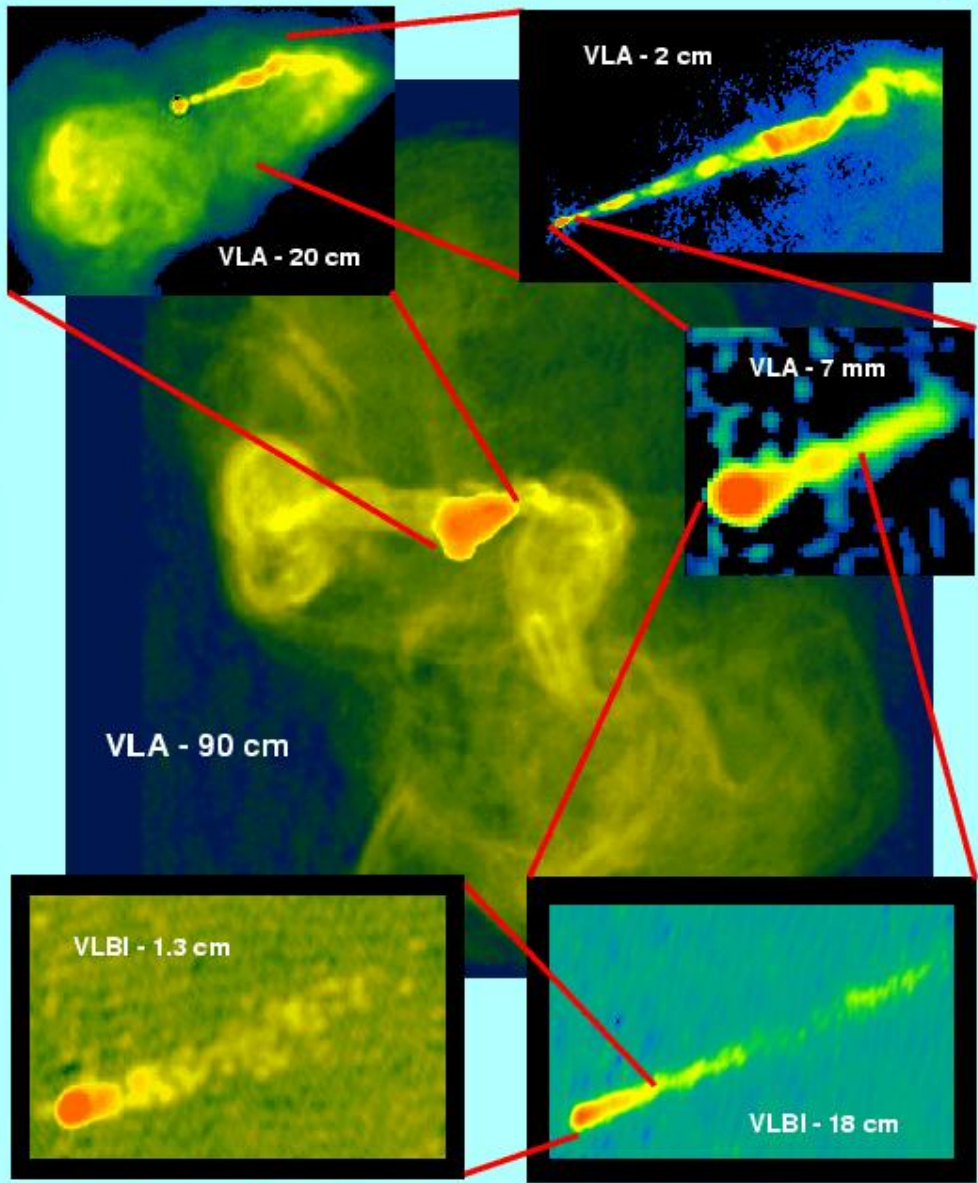


extragalactic jets – radio observations

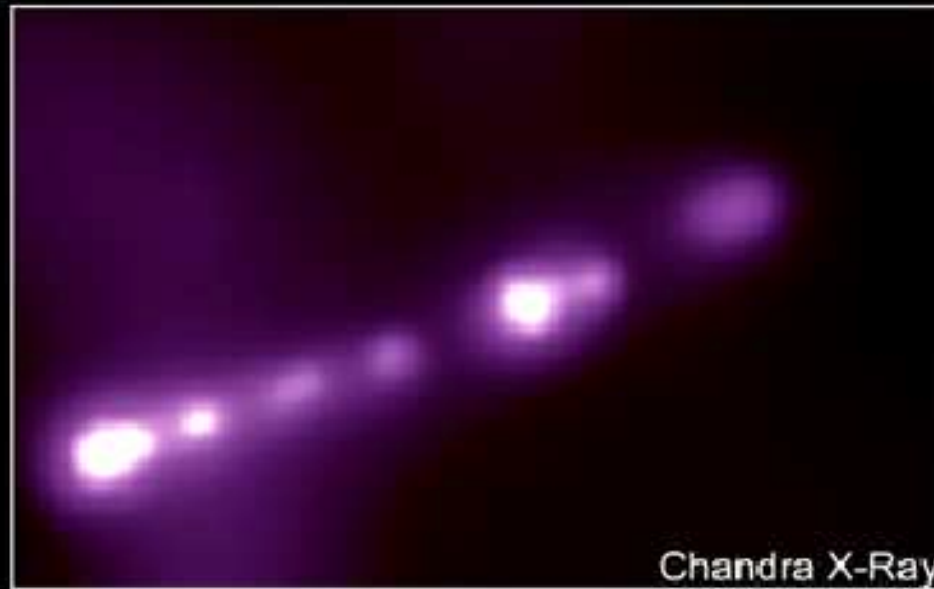
Jets are a **common ingredient of radio-loud AGNs** detected and imaged at very different spatial scales with different radio interferometry arrays (kpc scales: VLA, Merlin; pc scales: VLBA, EVN, Global VLBI...)



M87 -- From 200,000 Light-Years to 0.2 Light-Year



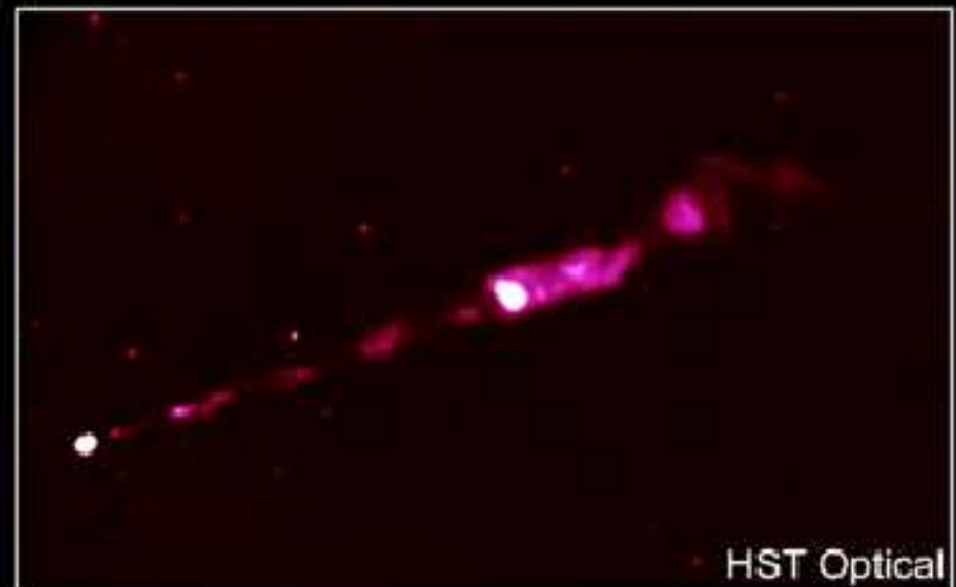
Credit: Frazer Owen (NRAO), John Biretta (STScI) and colleagues.
The National Radio Astronomy Observatory is a facility of the National Science Foundation, operated under cooperative agreement by Associated Universities, Inc.



Chandra X-Ray



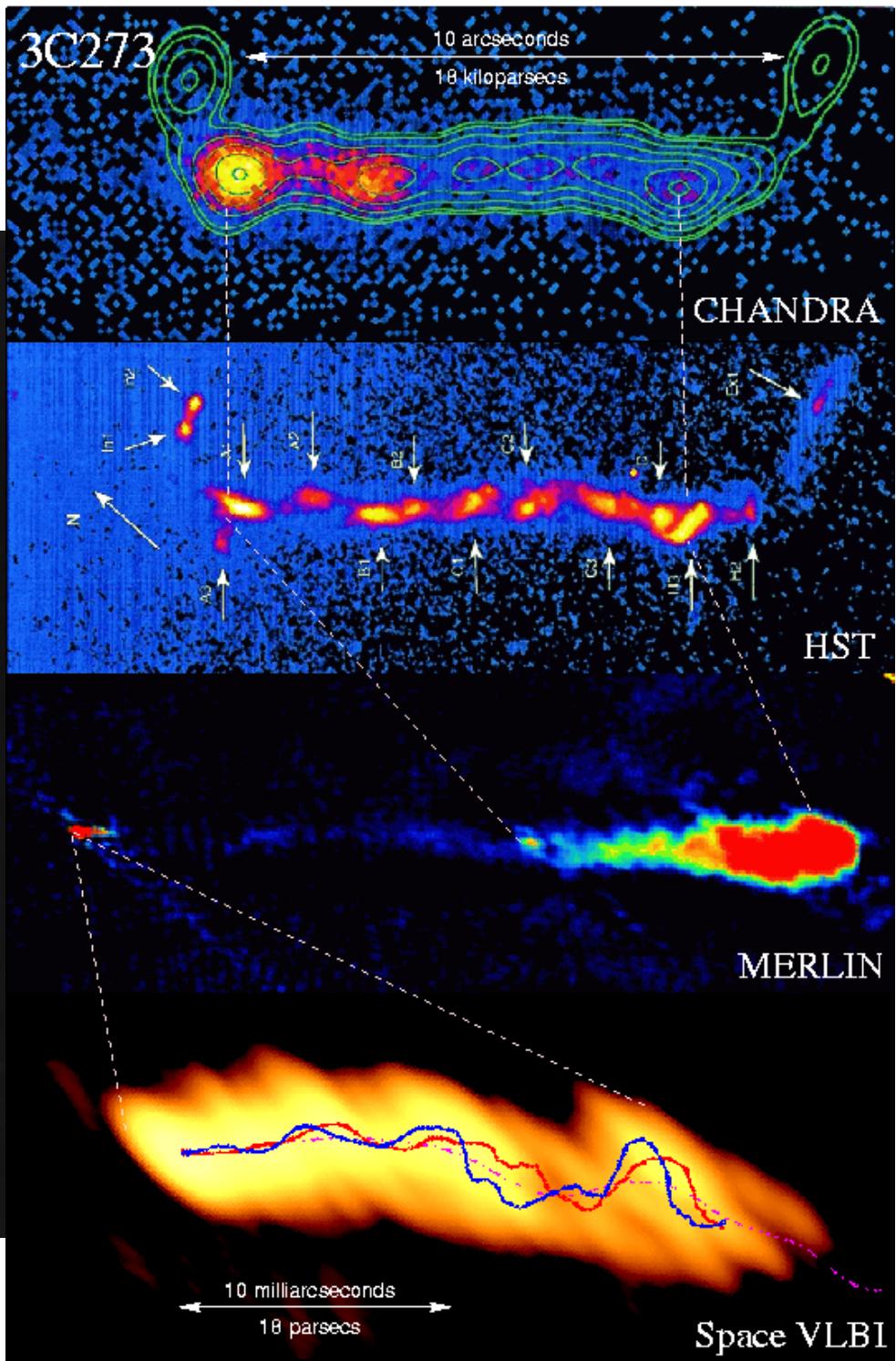
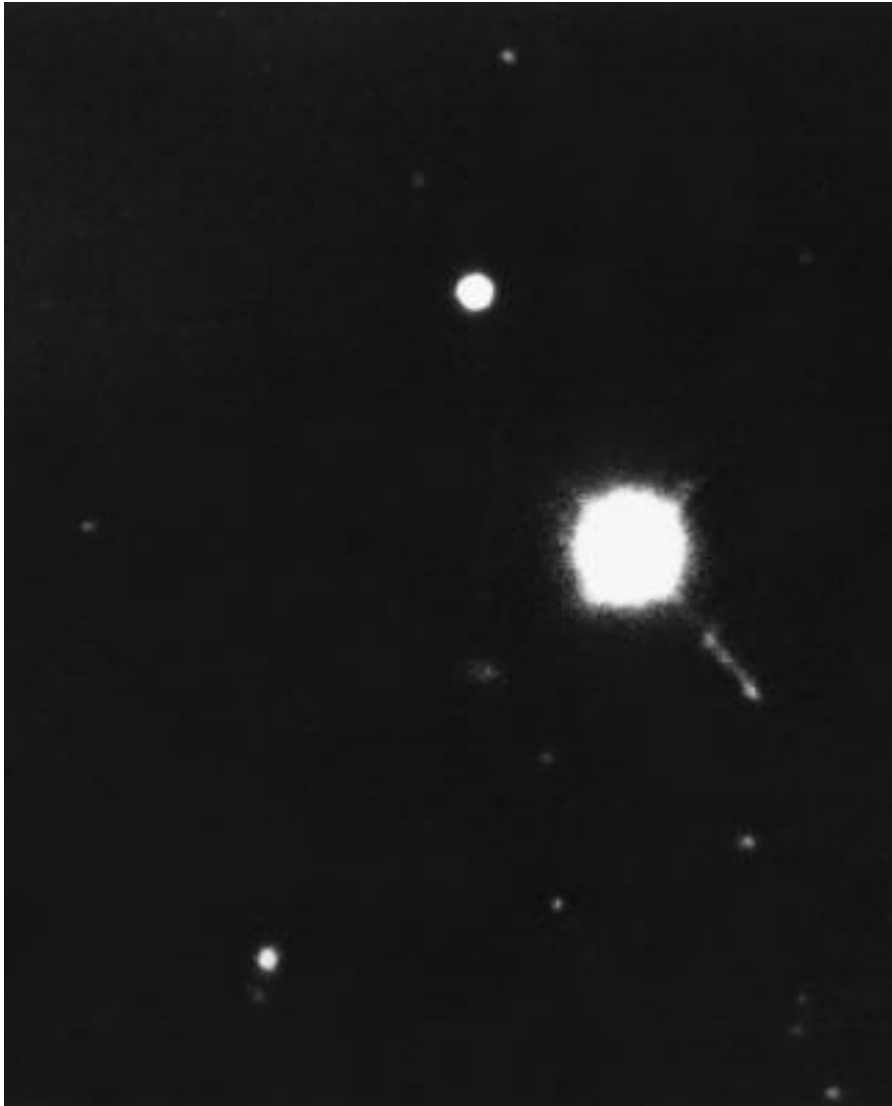
VLA Radio



HST Optical

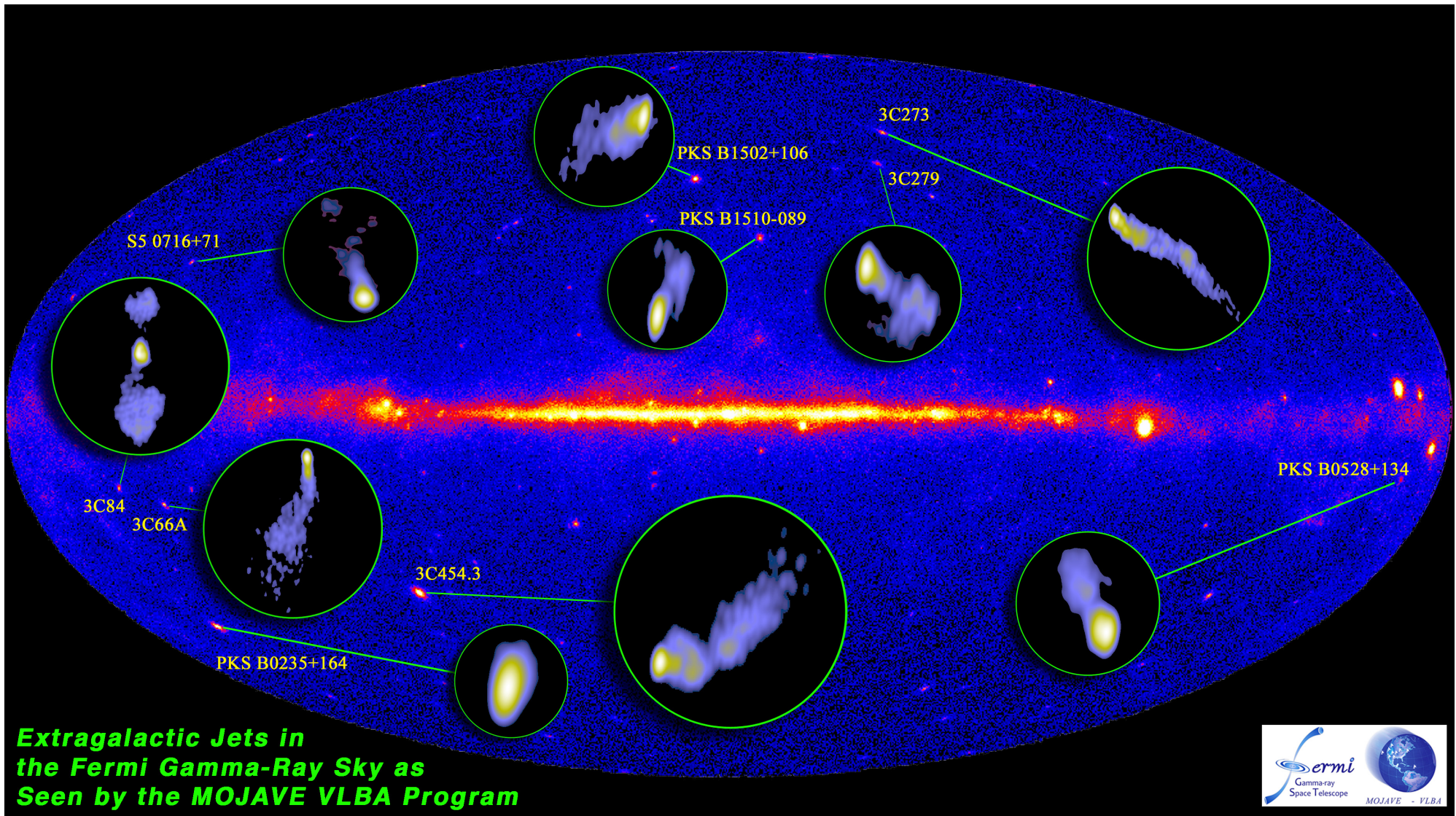
Credit: X-ray: NASA/CXC/MIT/H.Marshall et al. Radio: F. Zhou, F.Owen (NRAO), J.Biretta (STScI)

Optical: NASA/STScI/UMBC/E.Perlman et al.



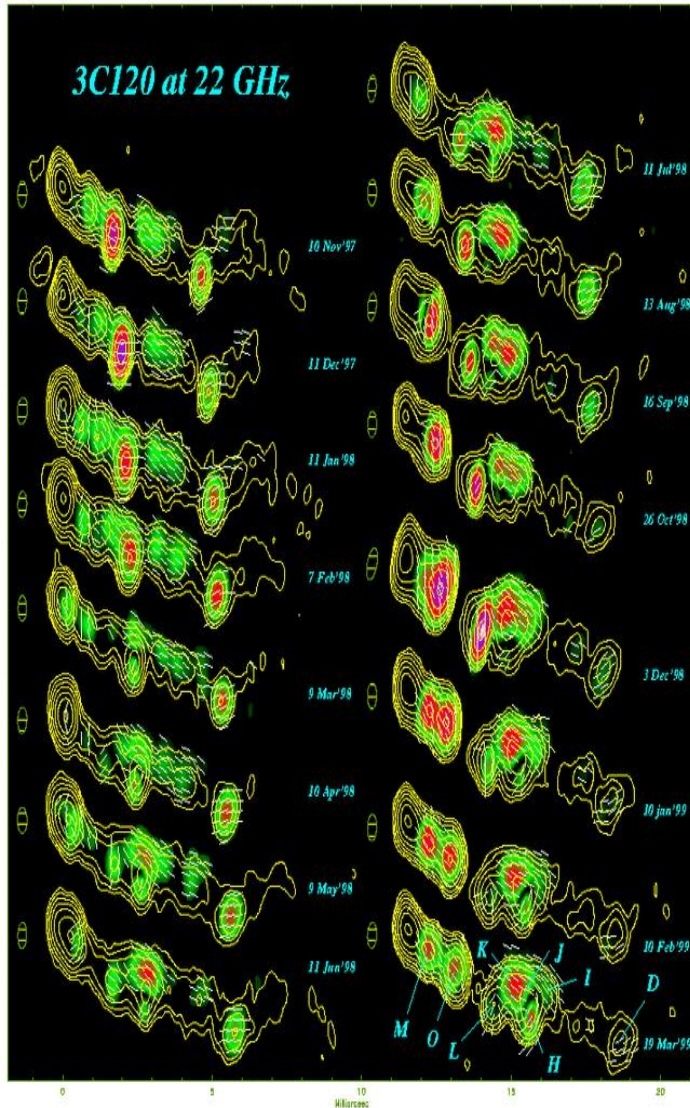
extragalactic jets – multifrequency observations

Jets are a common ingredient of radio-loud AGNs detected also at optical (HST), X-rays (Chandra) and gamma-rays (Fermi).



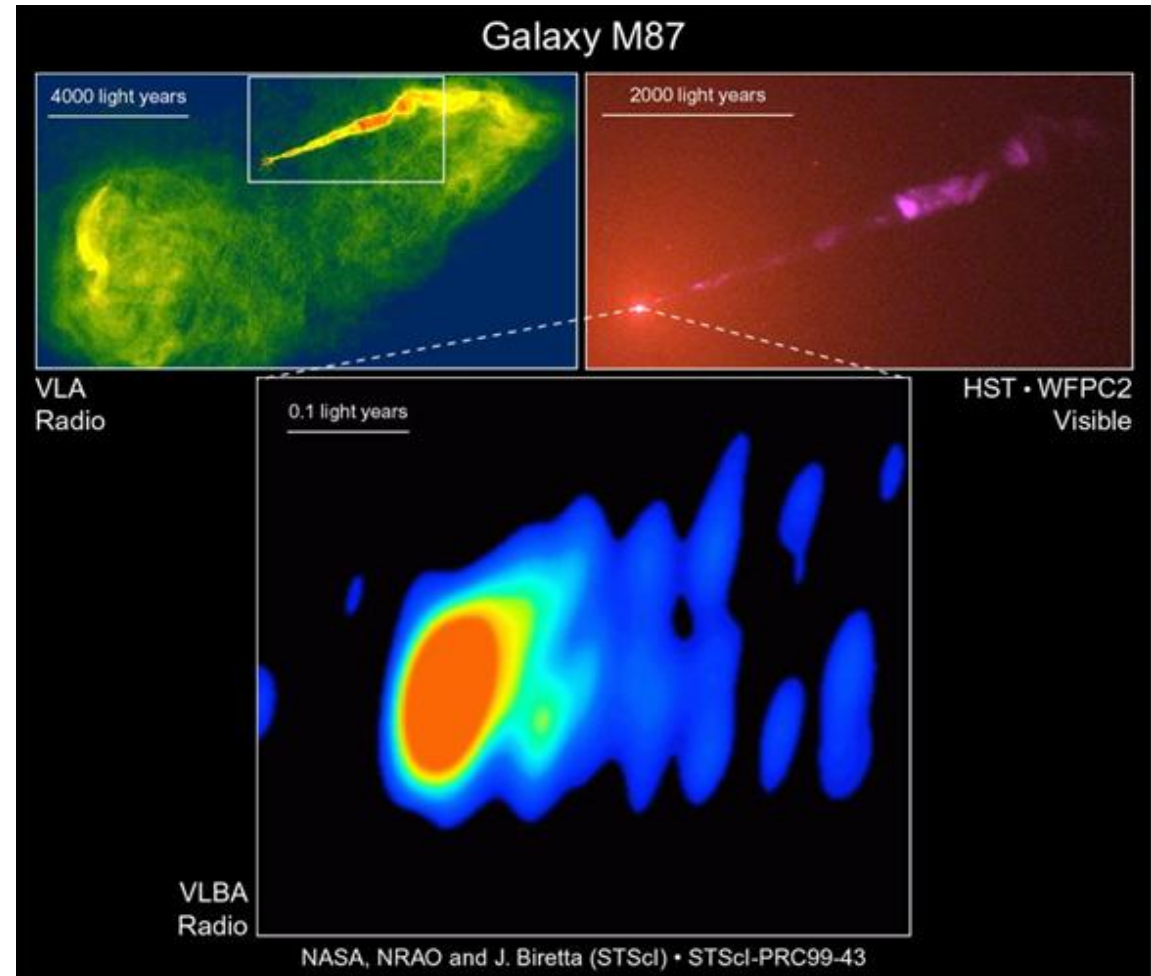
The smallest scales

Pc scales: Superluminal motion, one-sidedness



3C120, VLBA
Gómez et al. 2000

Sub-pc scale: Collimation and acceleration



M87, VLA/VLBA
Junor et al. 1999

Relativitat especial en acció

Rybicki & Lightman. Radiative processes in Astrophysics.

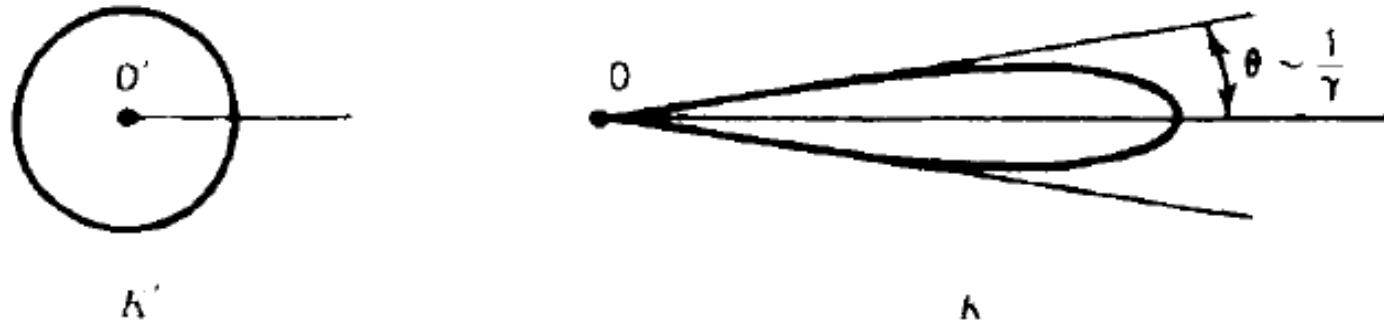
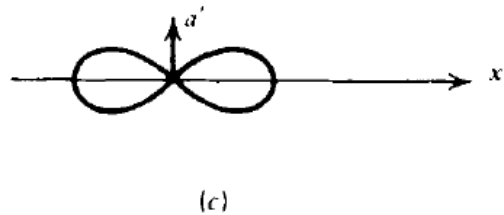


Figure 4.3 *Relativistic beaming of radiation emitted isotropically in the rest frame K' .*



Dipole radiation pattern

Figure 4.11c *Same as a.*

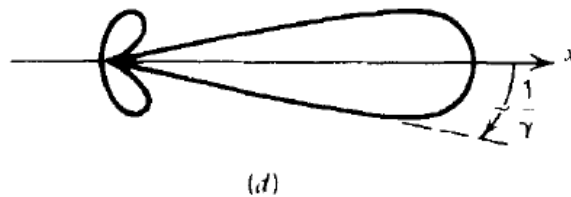
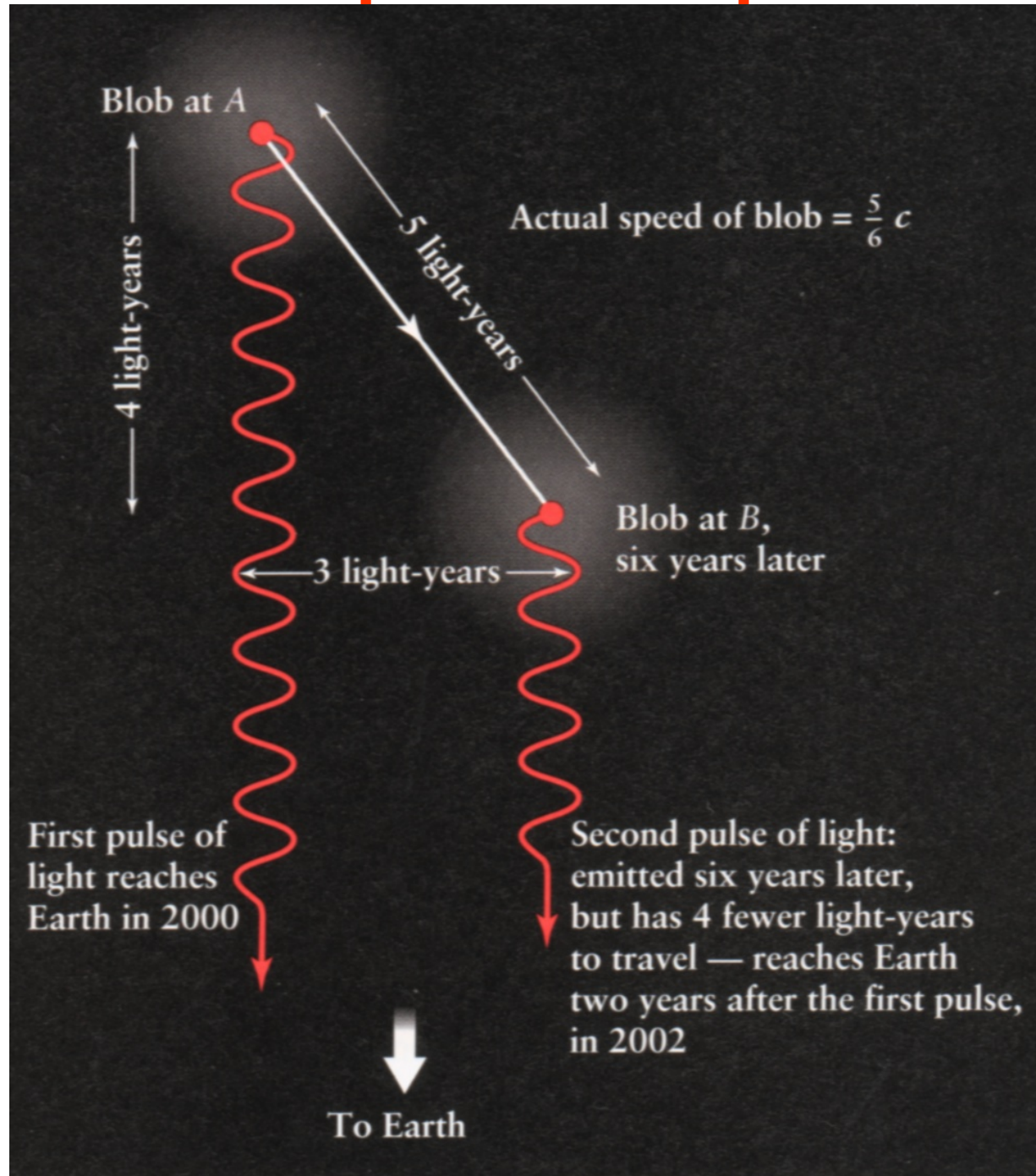


Figure 4.11d *Angular distribution of radiation emitted by a particle with perpendicular acceleration and velocity.*

Moviments aparents superlumínics



Moviments aparents superlumínics

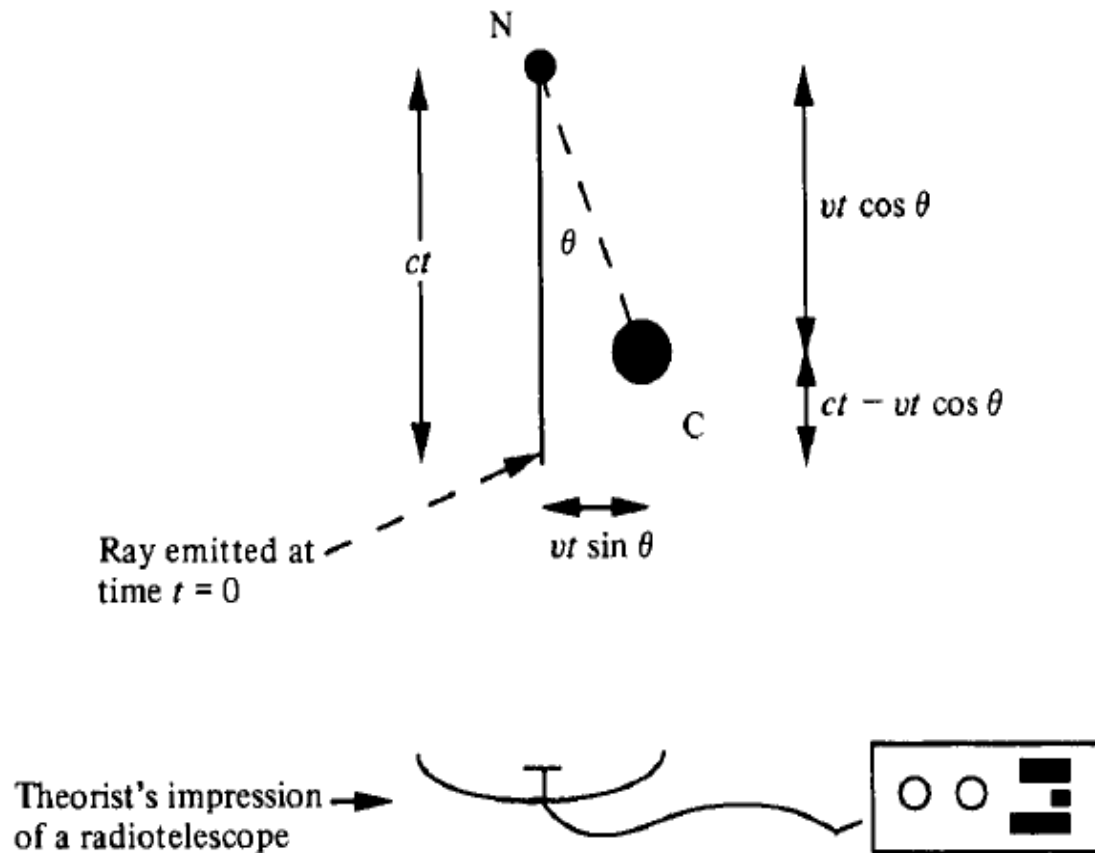
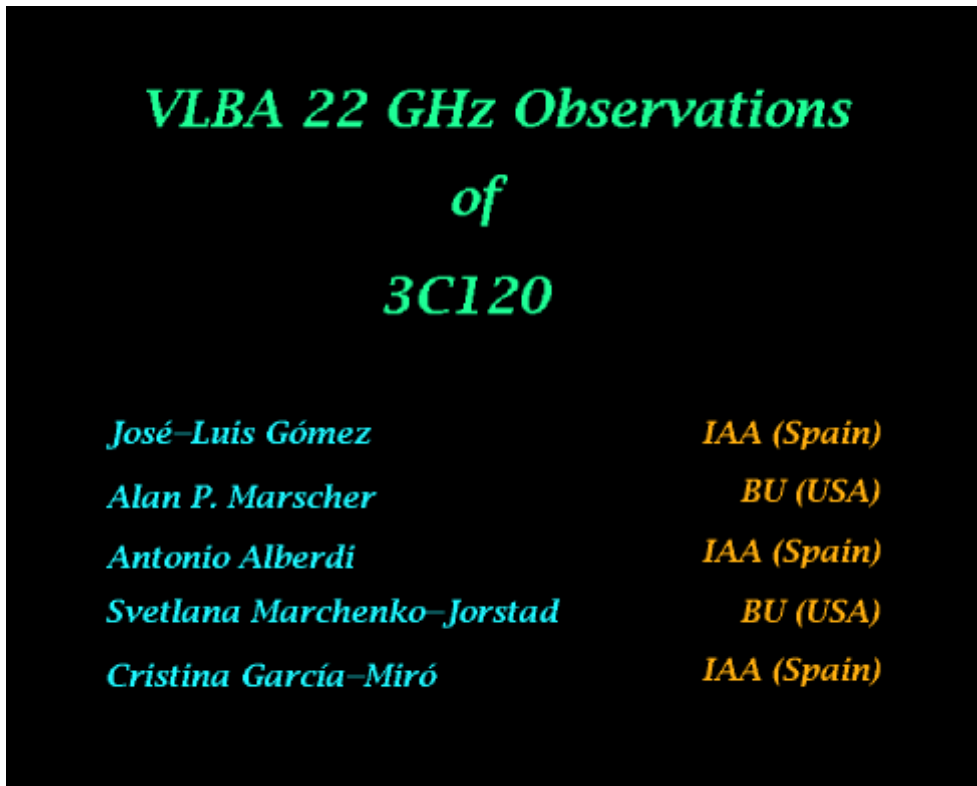


Fig. 4.1. Illustrating how superluminal motion might occur as a result of relativistic motion of the component C directed at an angle θ to the observer (O)'s line of sight with speed $v = c\beta$. On being ejected from the nucleus N , component C emits radiation towards the observer. At time t later, C has moved across the sky a distance $ct\beta \sin \theta$, and is only a distance $ct\beta(1 - \beta \cos \theta)$ behind the radiation it emitted on leaving N . Thus O sees the travel time of C compressed to $t(1 - \beta \cos \theta)$ and deduces an apparent speed $c\beta \sin \theta / (1 - \beta \cos \theta)$ as in equation (4.1).

Evolution of parsec-scale jets

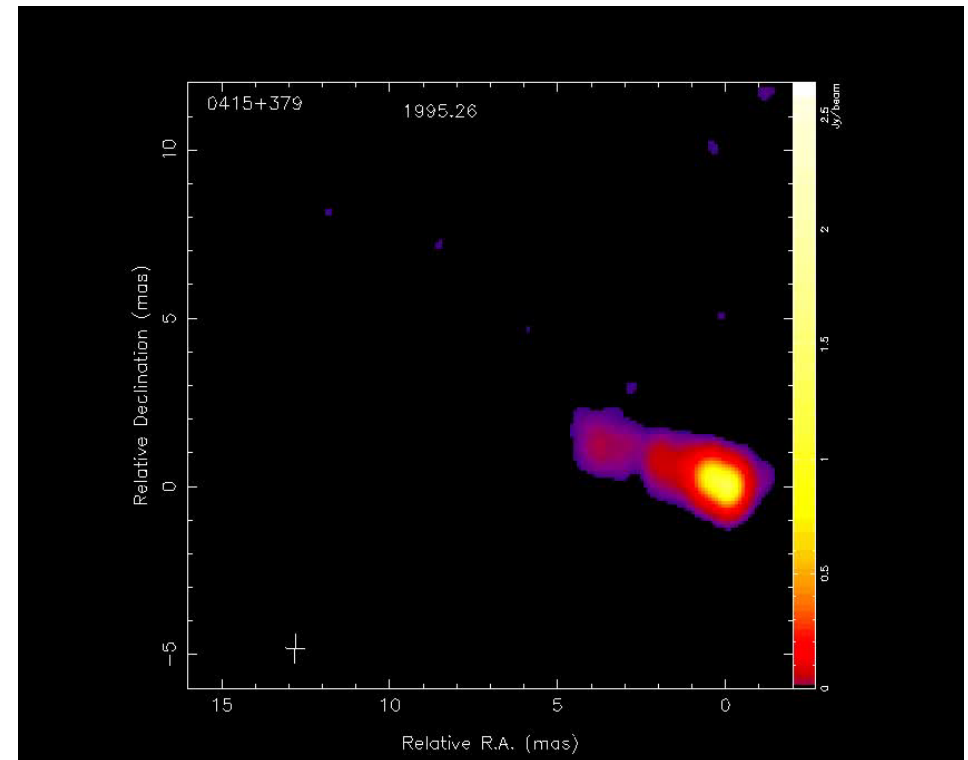
Very frequent observations can give deep insight into jet dynamics:

3C 120 – Gómez et al.



Gómez et al. 2000

3C 111 – MOJAVE

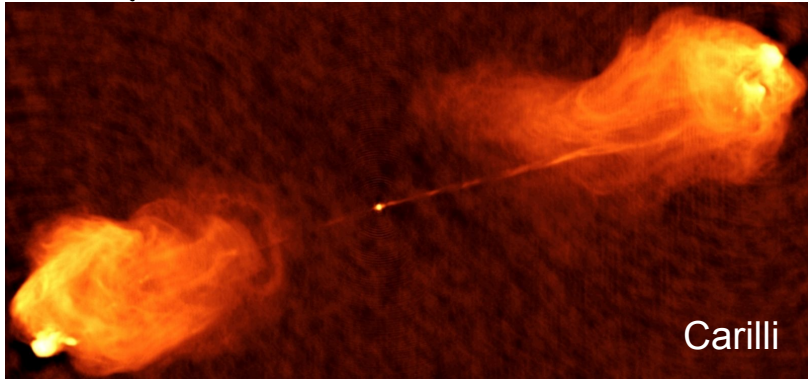


Kadler et al. 2008

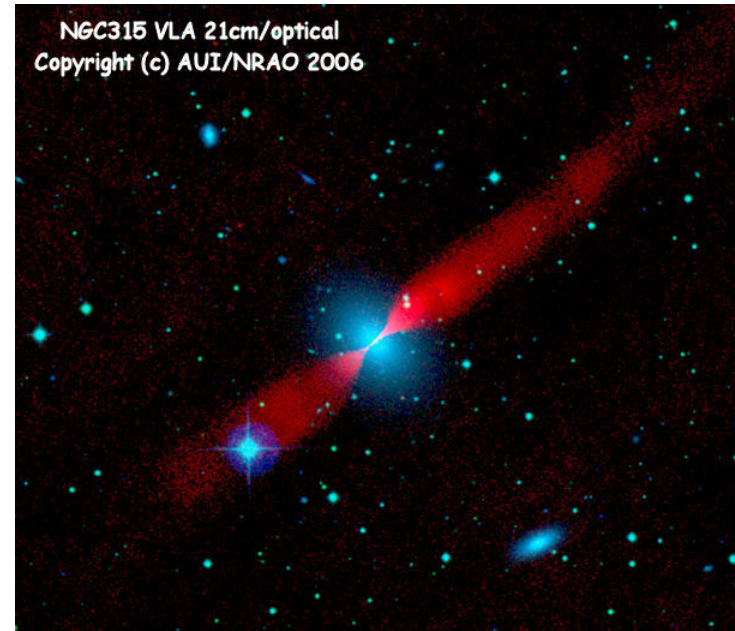
<http://www.physics.purdue.edu/astro/MOJAVE/index.html>

Kiloparsec scales: FRI/FRII dichotomy

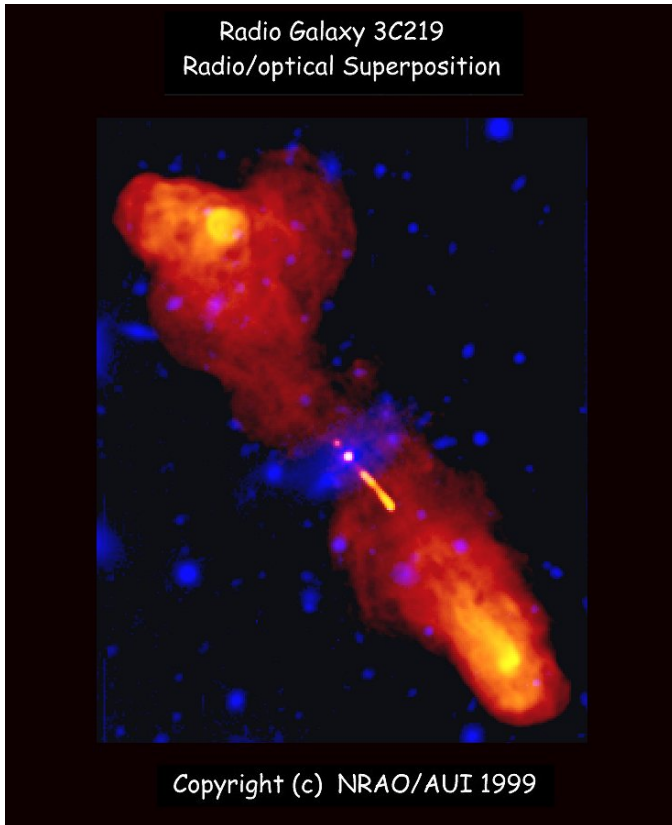
jet power



Carilli



NGC315 VLA 21cm/optical
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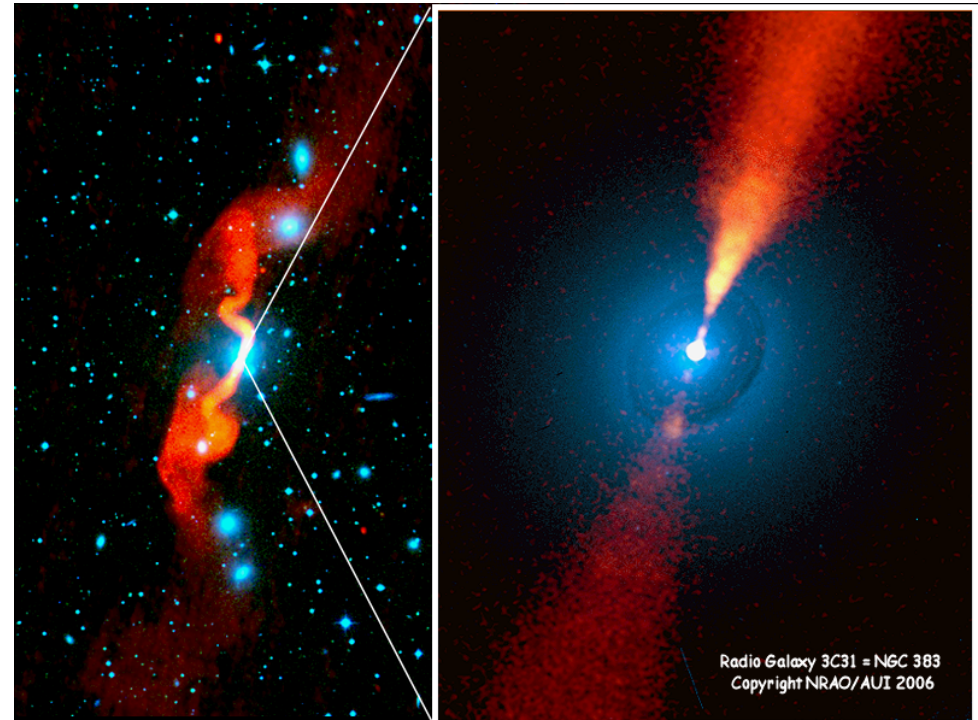


Radio Galaxy 3C219
Radio/optical Superposition

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FRII

FRI

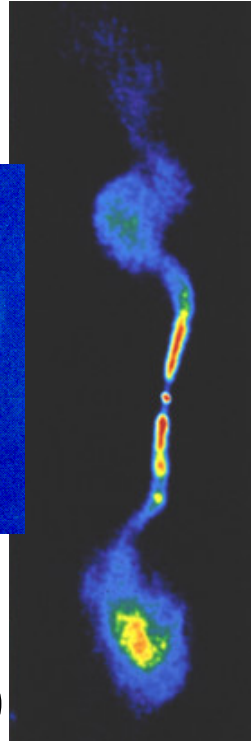
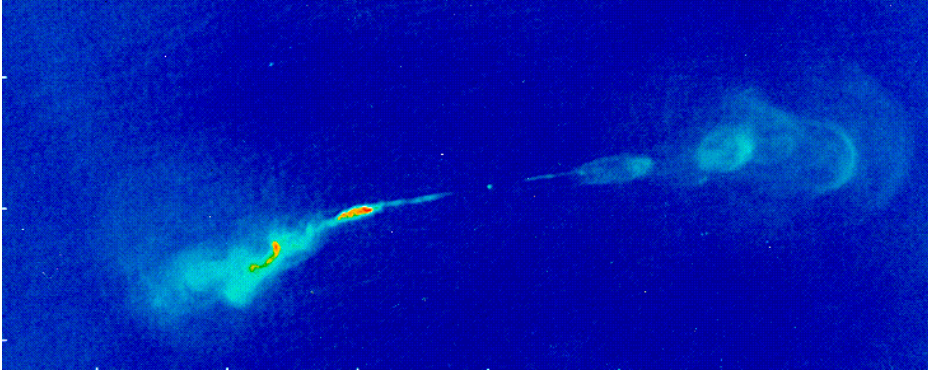


Radio Galaxy 3C31 = NGC 383
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A. Bridle's gallery

Kiloparsec scales: FRI/FRII dichotomy

Hercules A: (Dreher & Feigelson 1984)

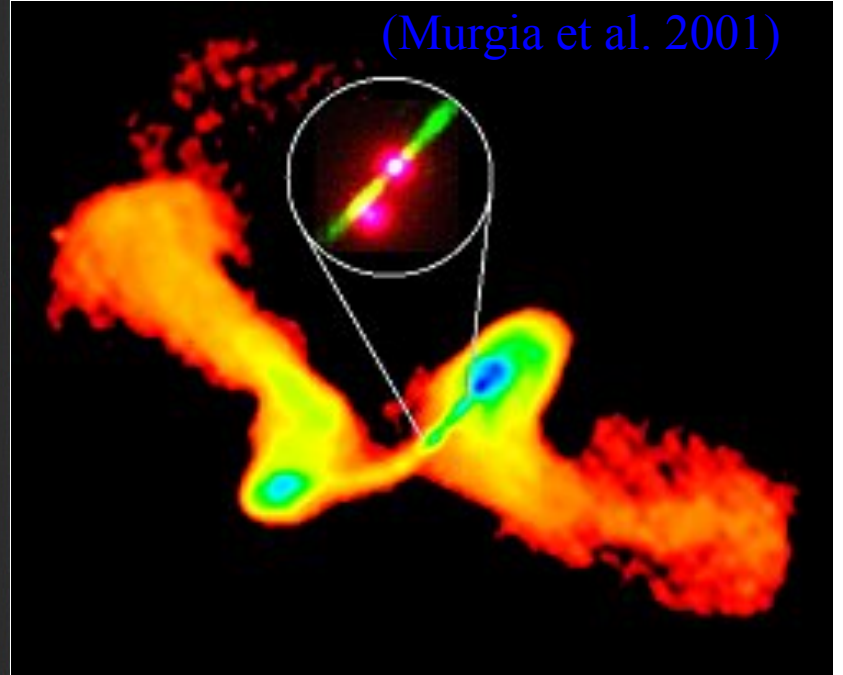


3C449

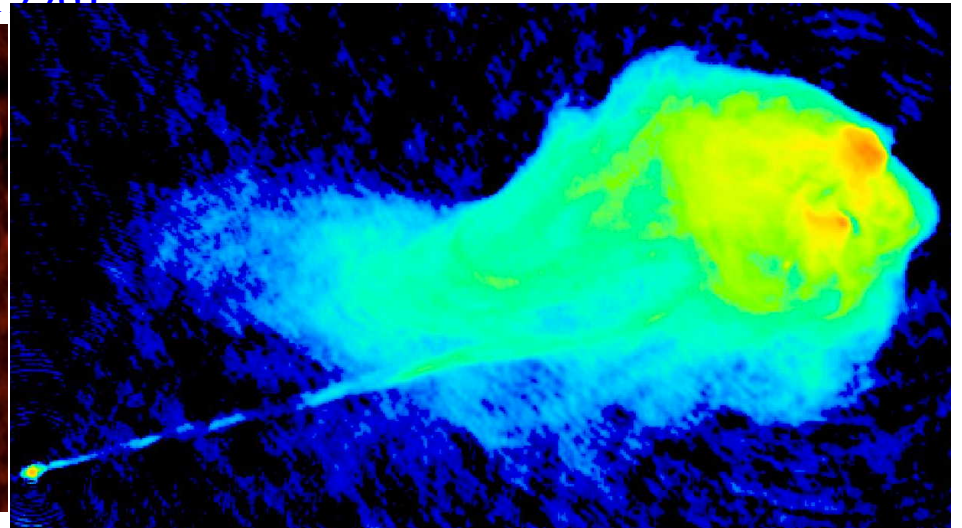
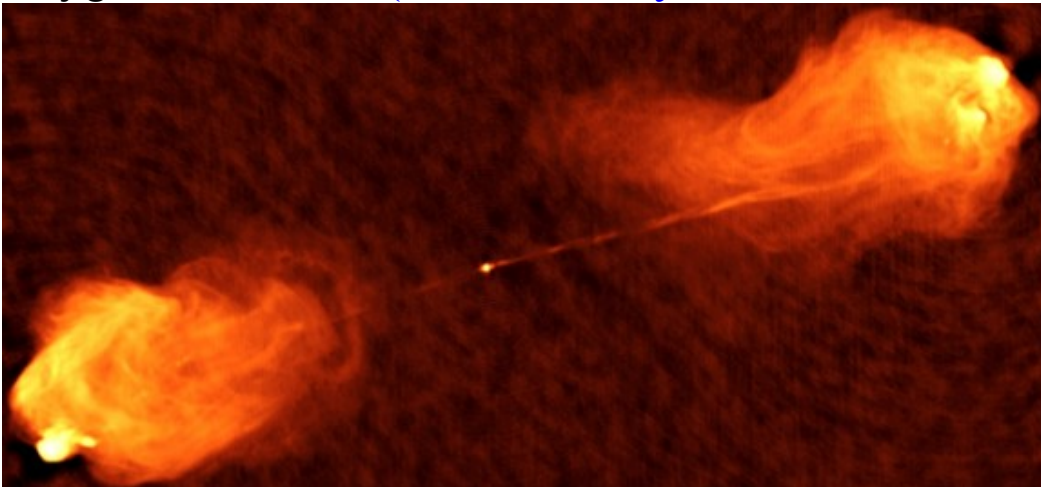
Hardcastle et al. (1998)

NGC 326

(Murgia et al. 2001)

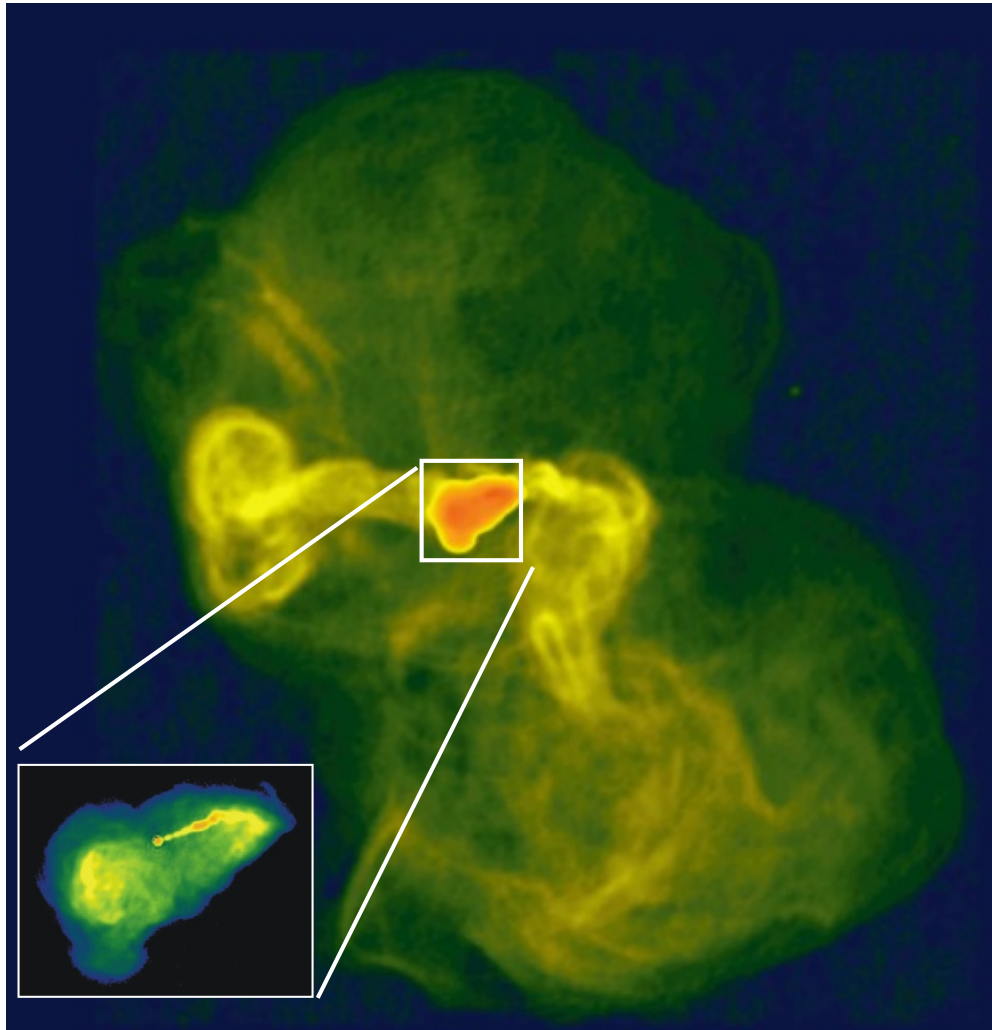


Cygnus A: FR II (Carilli, Perley, Barthel, Dreher 1996)

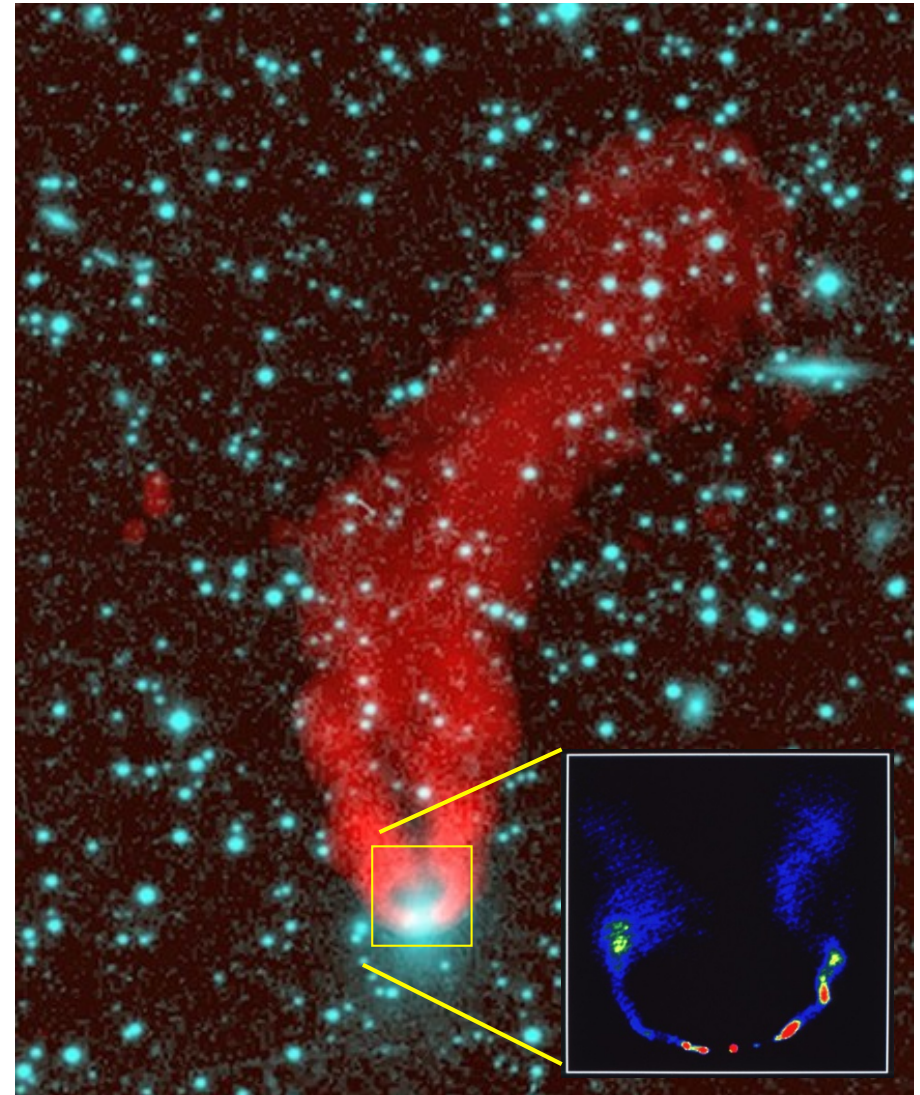


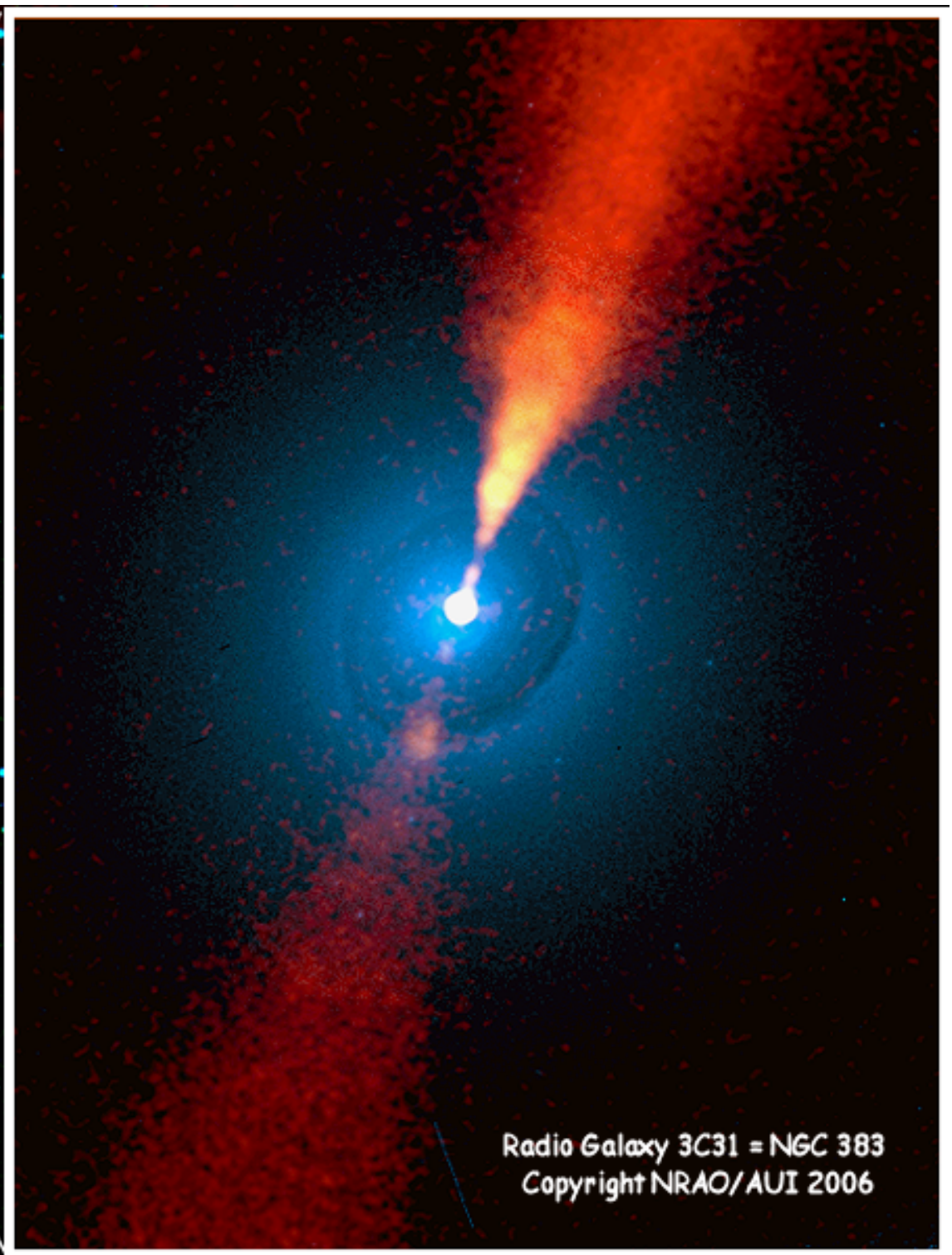
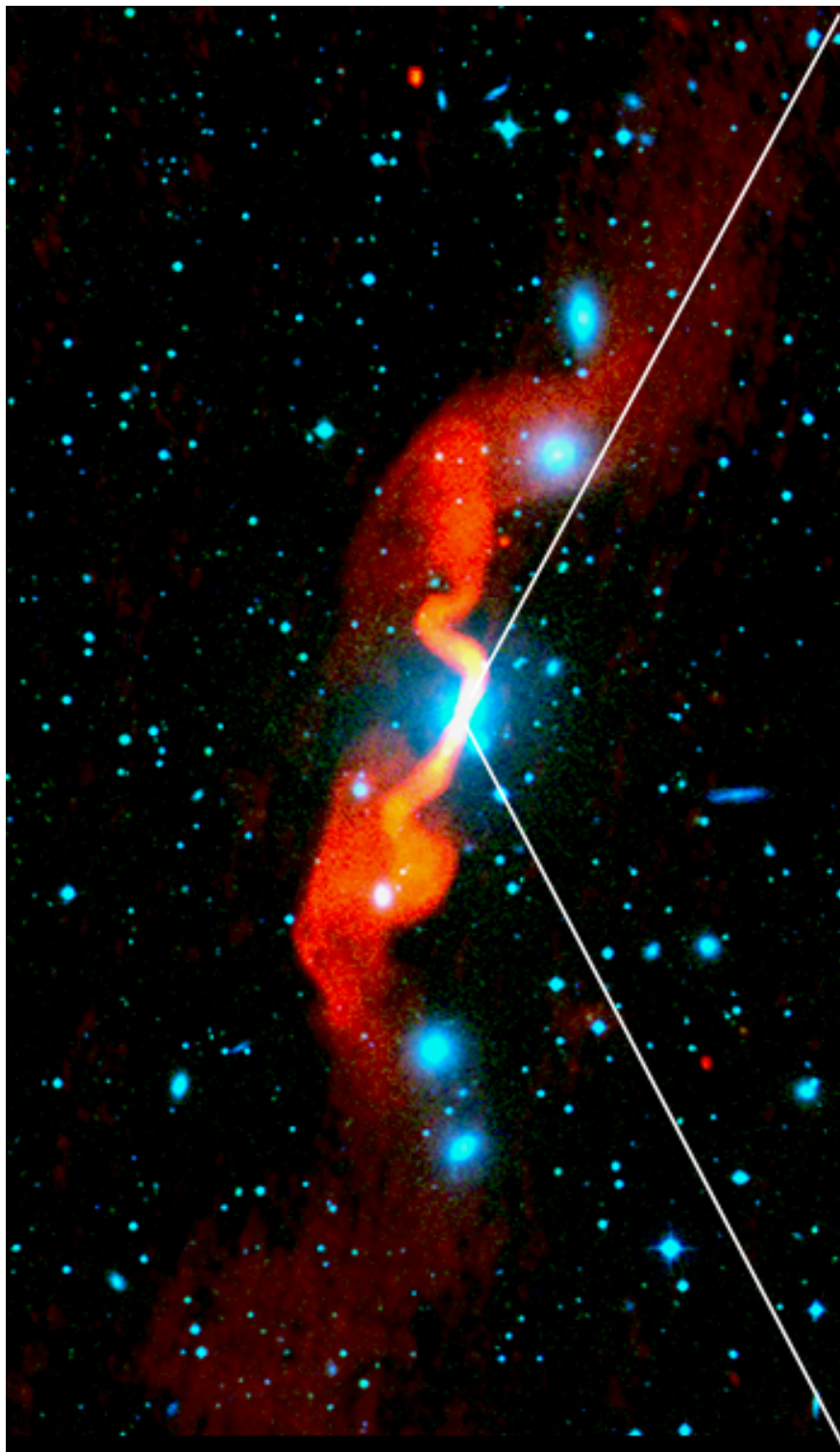
Kiloparsec scales: FRI/FRII dichotomy

M87: Virgo Cluster
(Owen, Biretta, & Eilek)



NGC 1265: Perseus Cluster
(O'Dea & Owen)

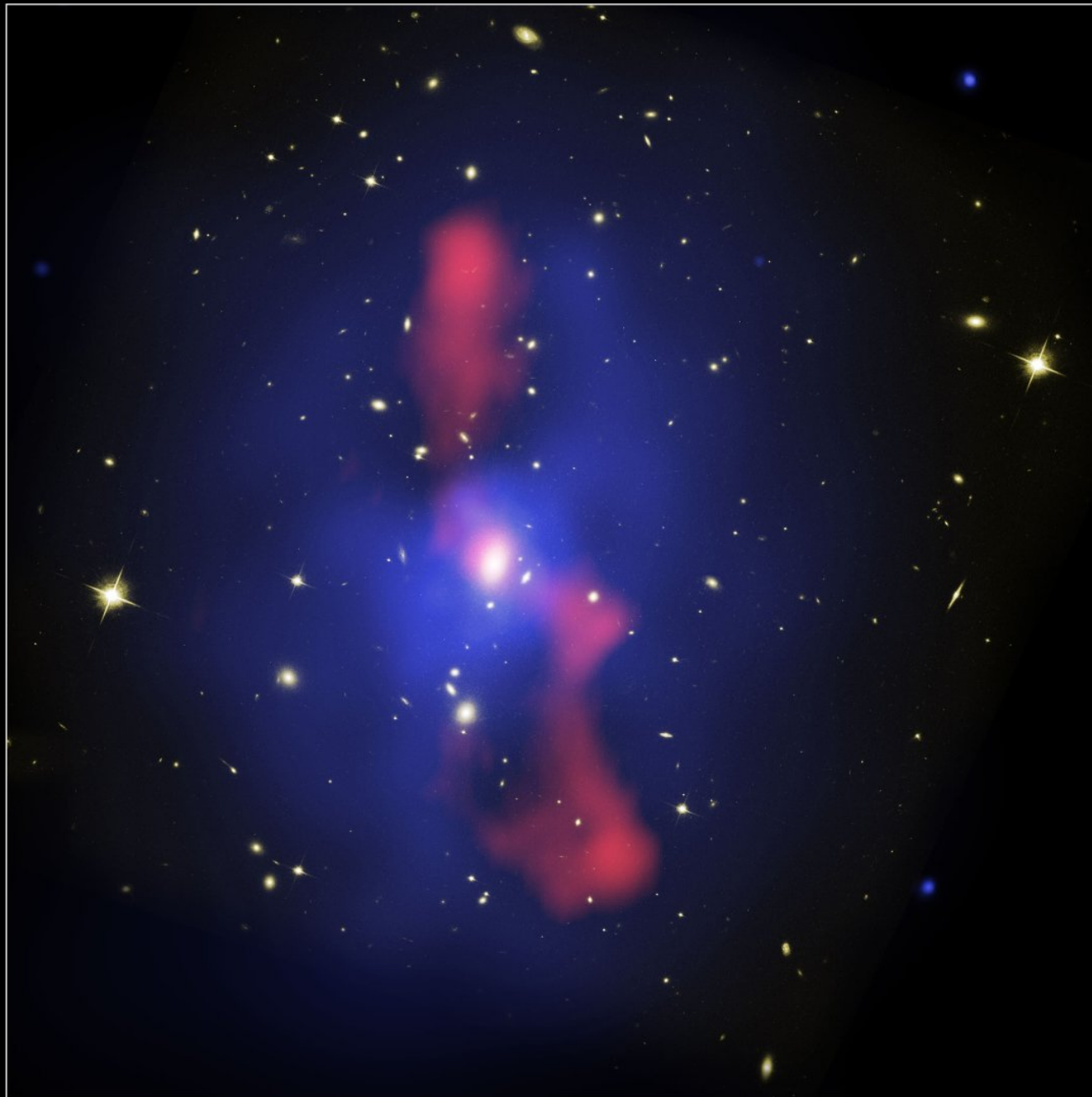




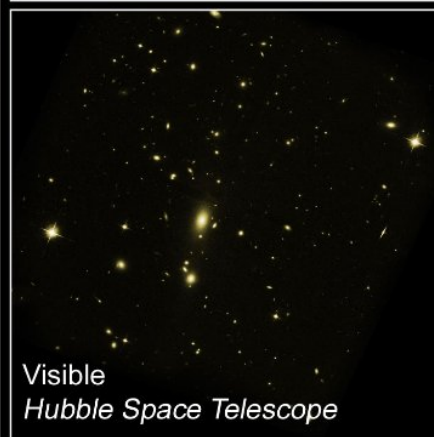
Radio Galaxy 3C31 = NGC 383
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Galaxy Cluster MS 0735.6+7421

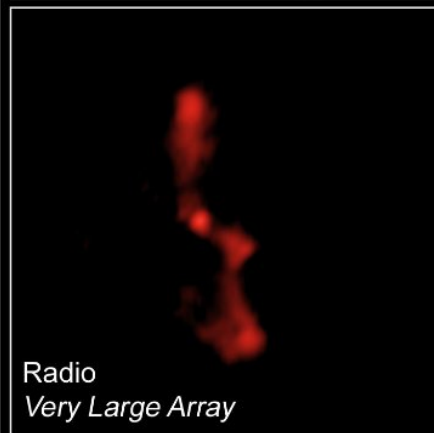
CXO ■ HST ■ VLA



X-ray
Chandra X-Ray Observatory

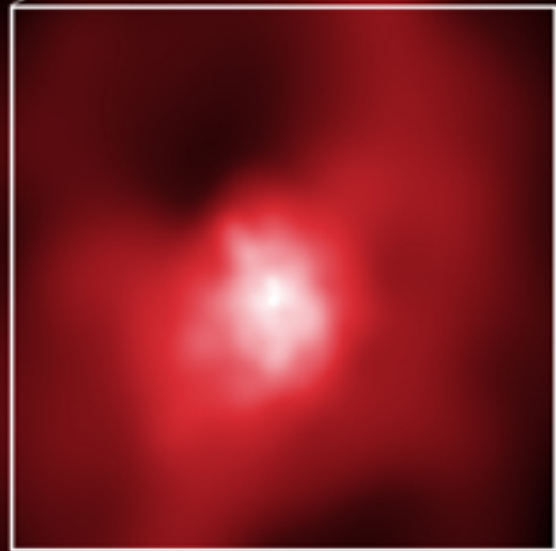


Visible
Hubble Space Telescope

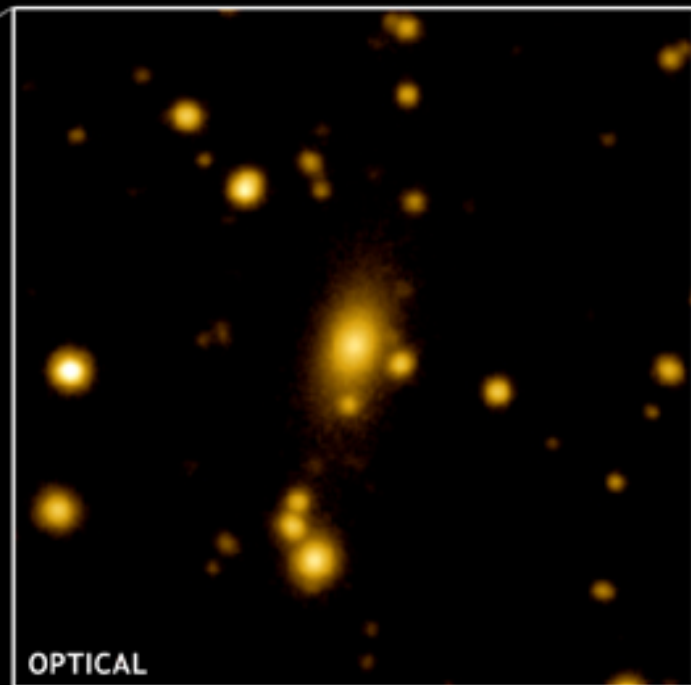


Radio
Very Large Array

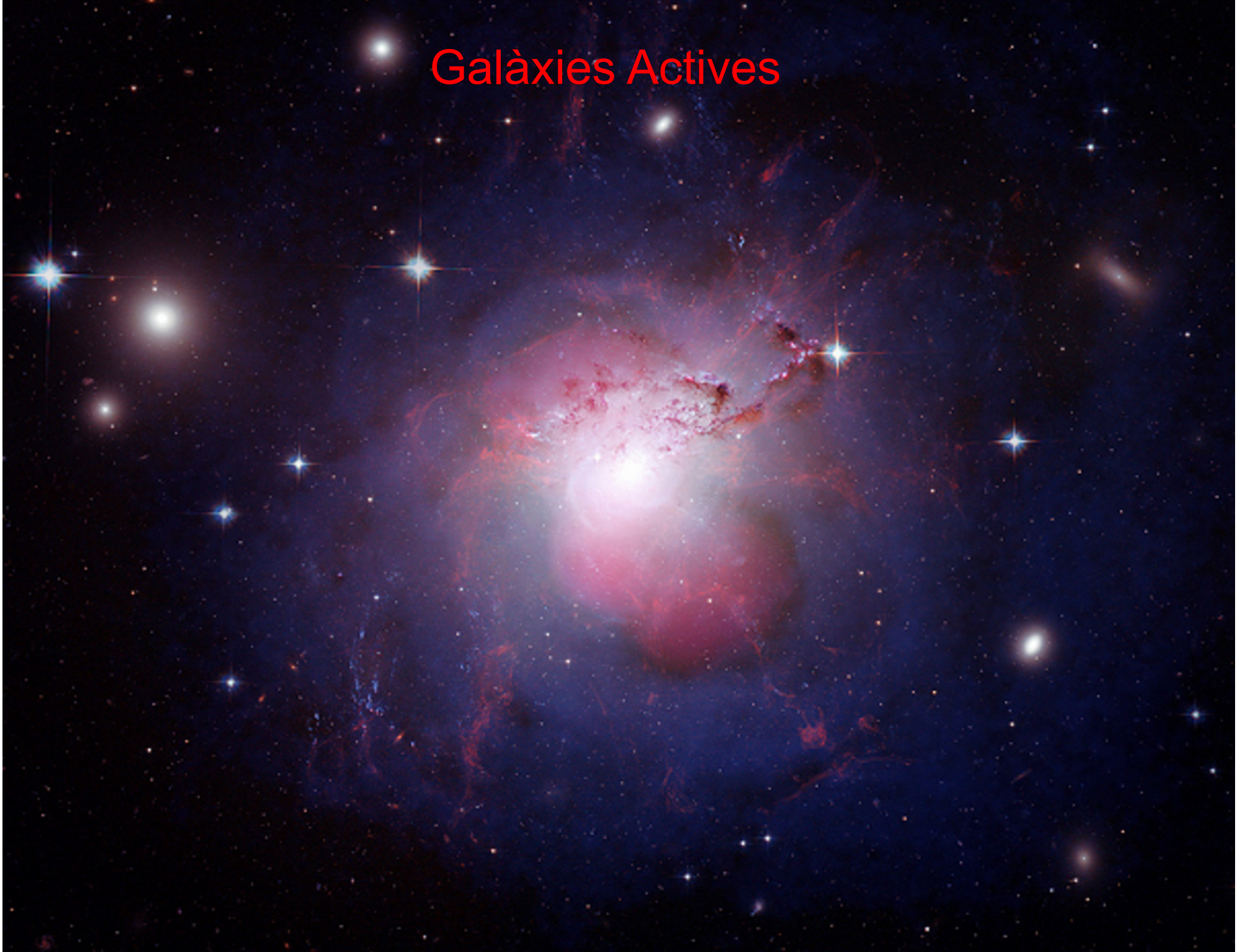
X-RAY

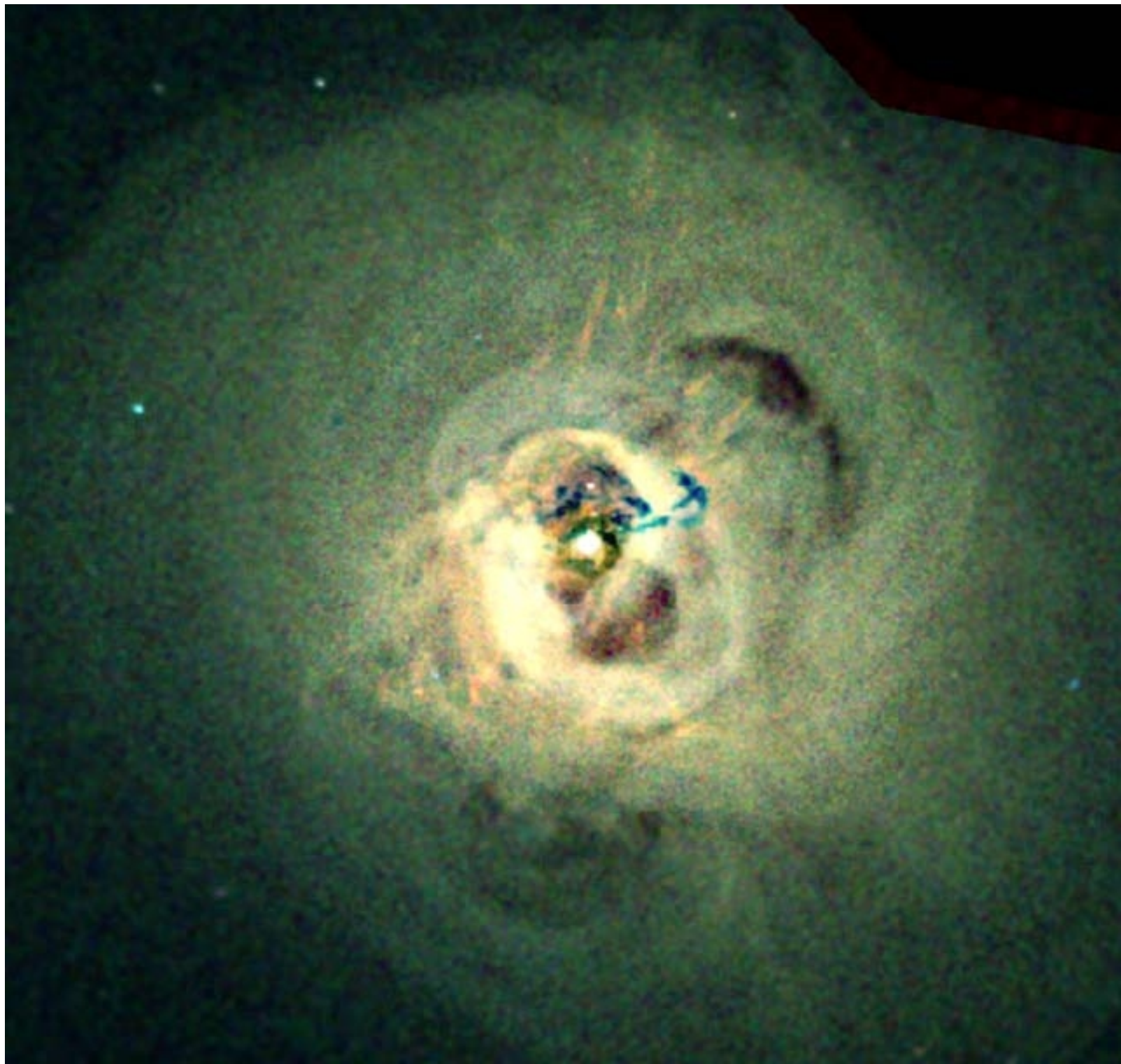


OPTICAL



Galaxies Actives



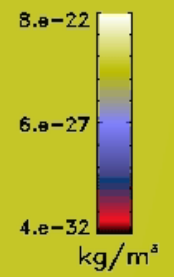


FRI jet

$t < 7.5 \cdot 10^6$ yrs

Logarithm of rest-mass density

1 kpc



Quadre resum d'evolució galàctica

