

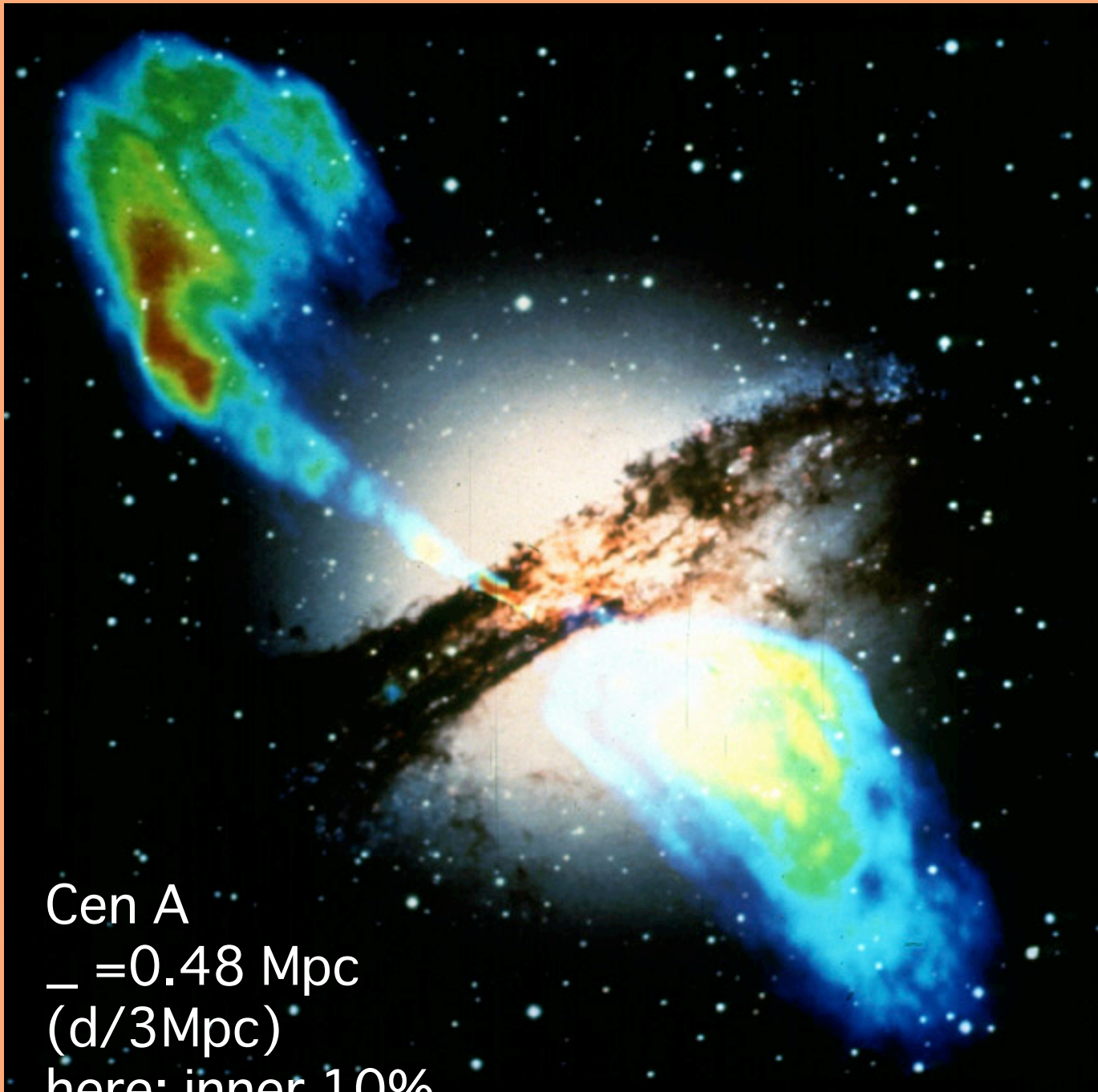
# THE ASTROPHYSICAL JETS

Wolfgang Kundt

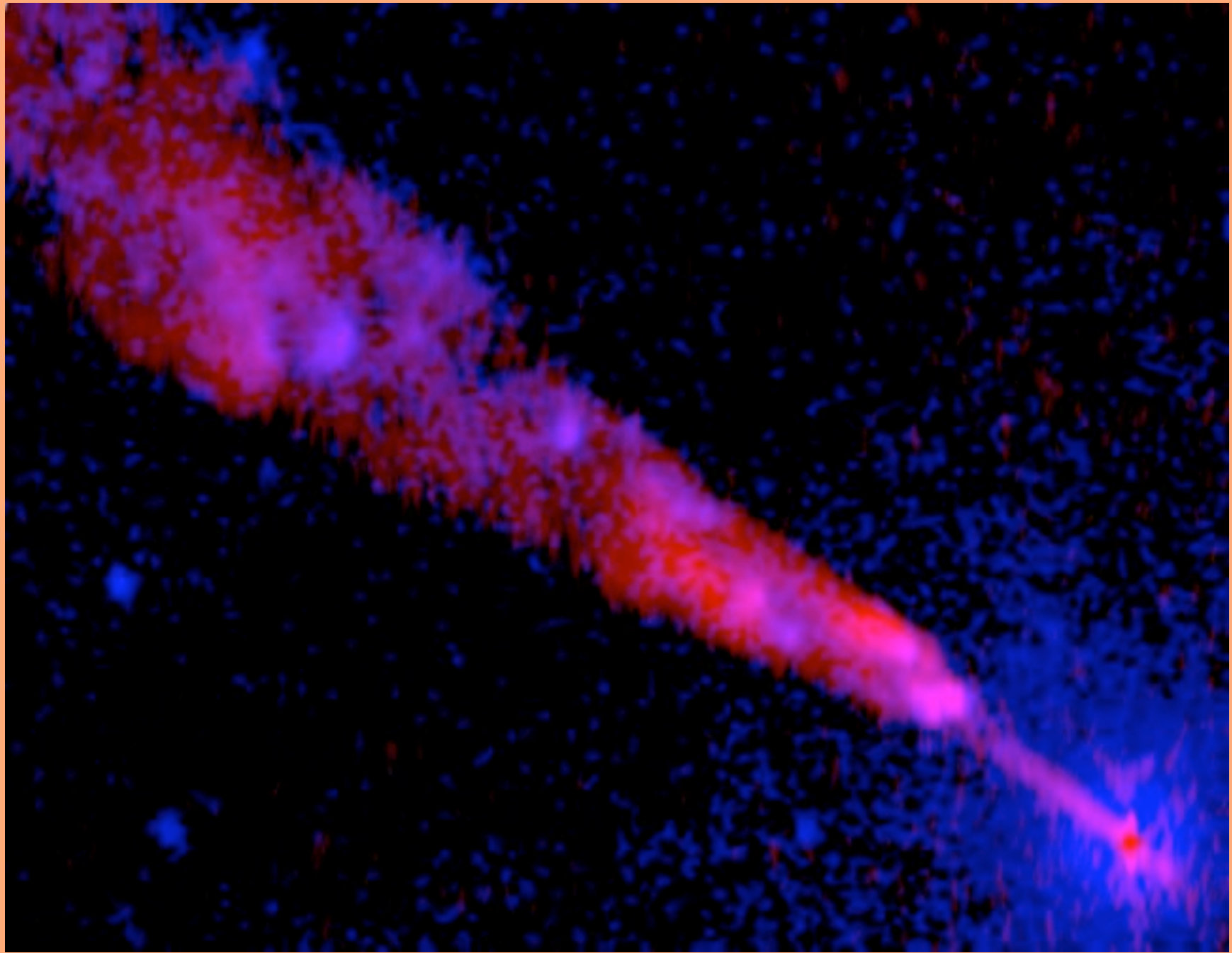
Washington, 27 July 2007

# THE BIPOLAR-FLOW FAMILY

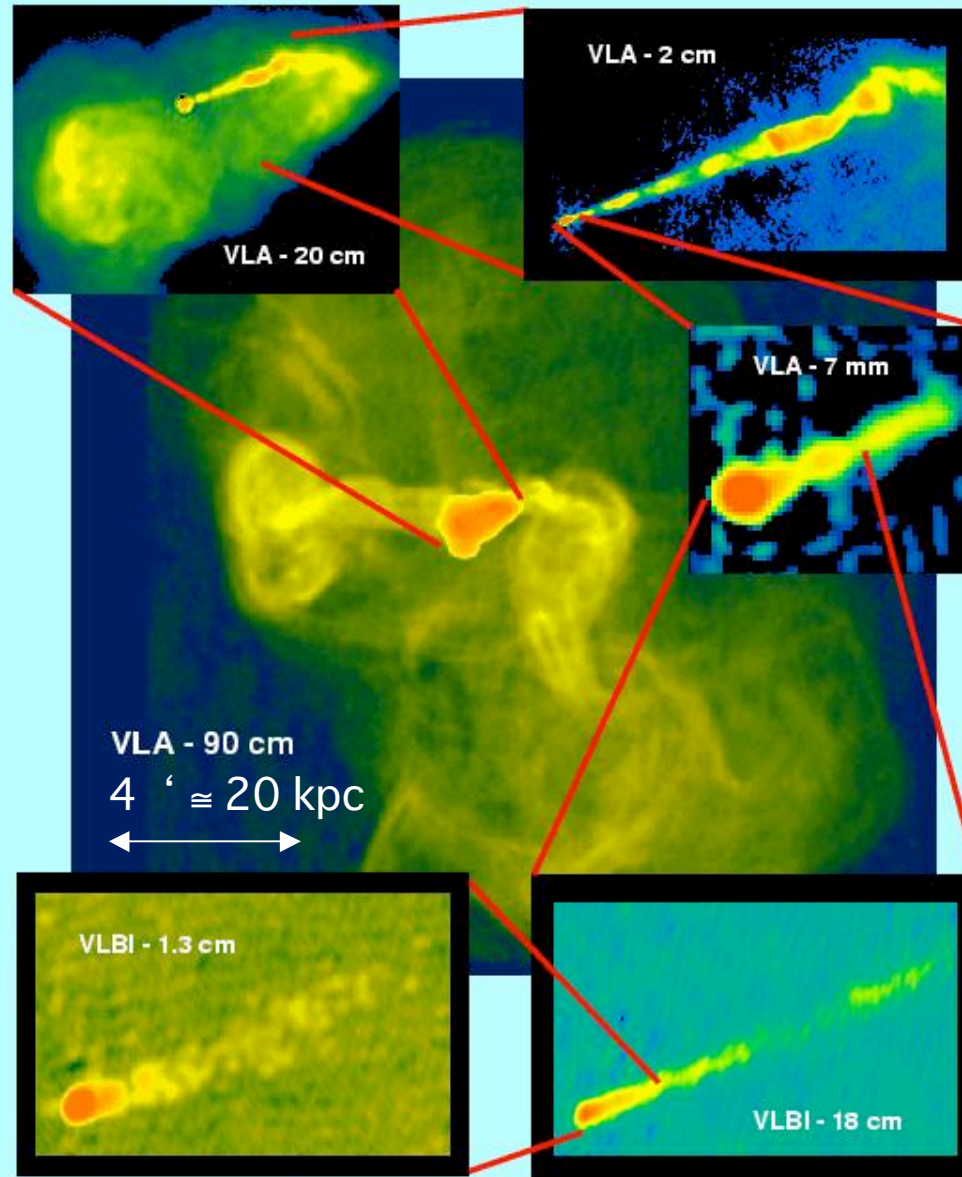
- Jets from the centers of (active) galaxies (AGN)
- Jets from young binary neutron stars (or BHCs).
- Jets from forming white dwarfs, inside planetary nebulae (PNe).
- Jets from newly-formed Stars (or YSOs), like our Sun.



Cen A  
 $r_{10} = 0.48$  Mpc  
( $d/3$  Mpc)  
here: inner 10%

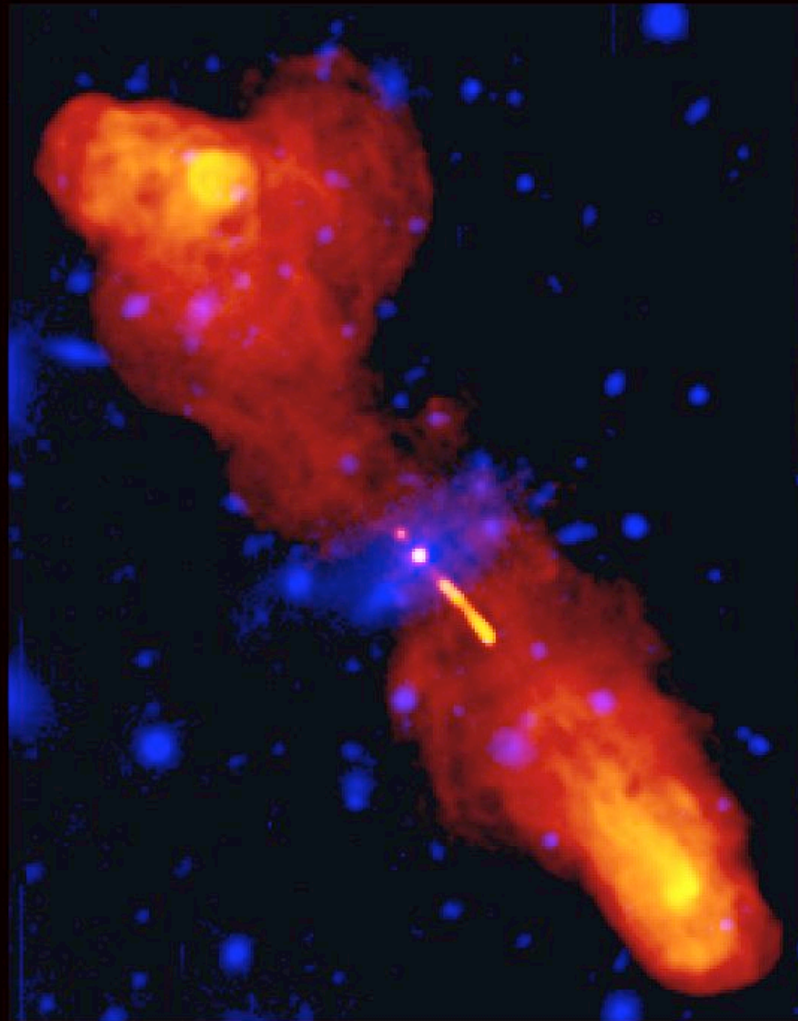


M87 -- From 200,000 Light-Years to 0.2 Light-Year



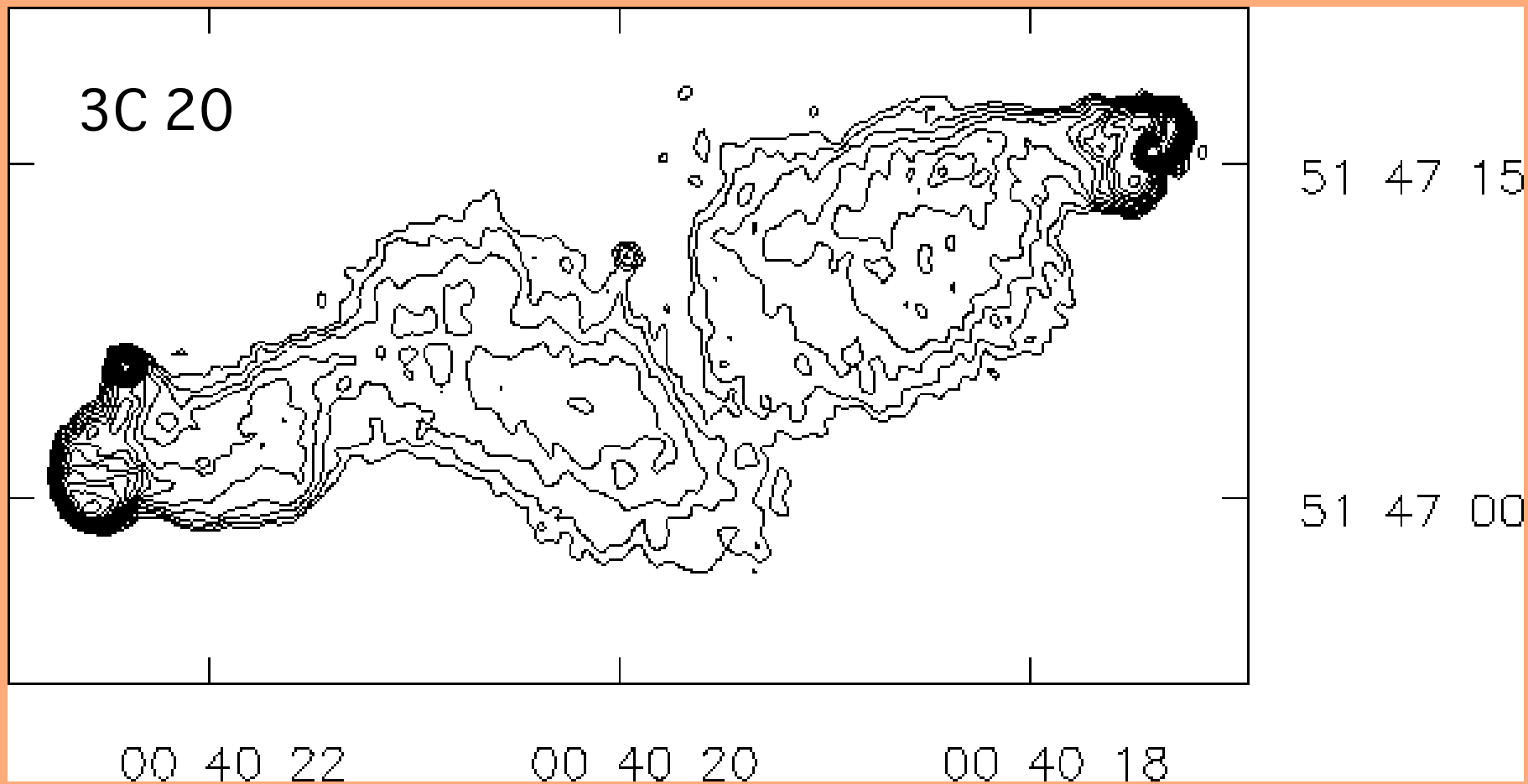
Credit: Frazer Owen (NRAO), John Biretta (STScI) and colleagues.  
The National Radio Astronomy Observatory is a facility of the National Science Foundation, operated under cooperative agreement by Associated Universities, Inc.

Radio Galaxy 3C219  
Radio/optical Superposition

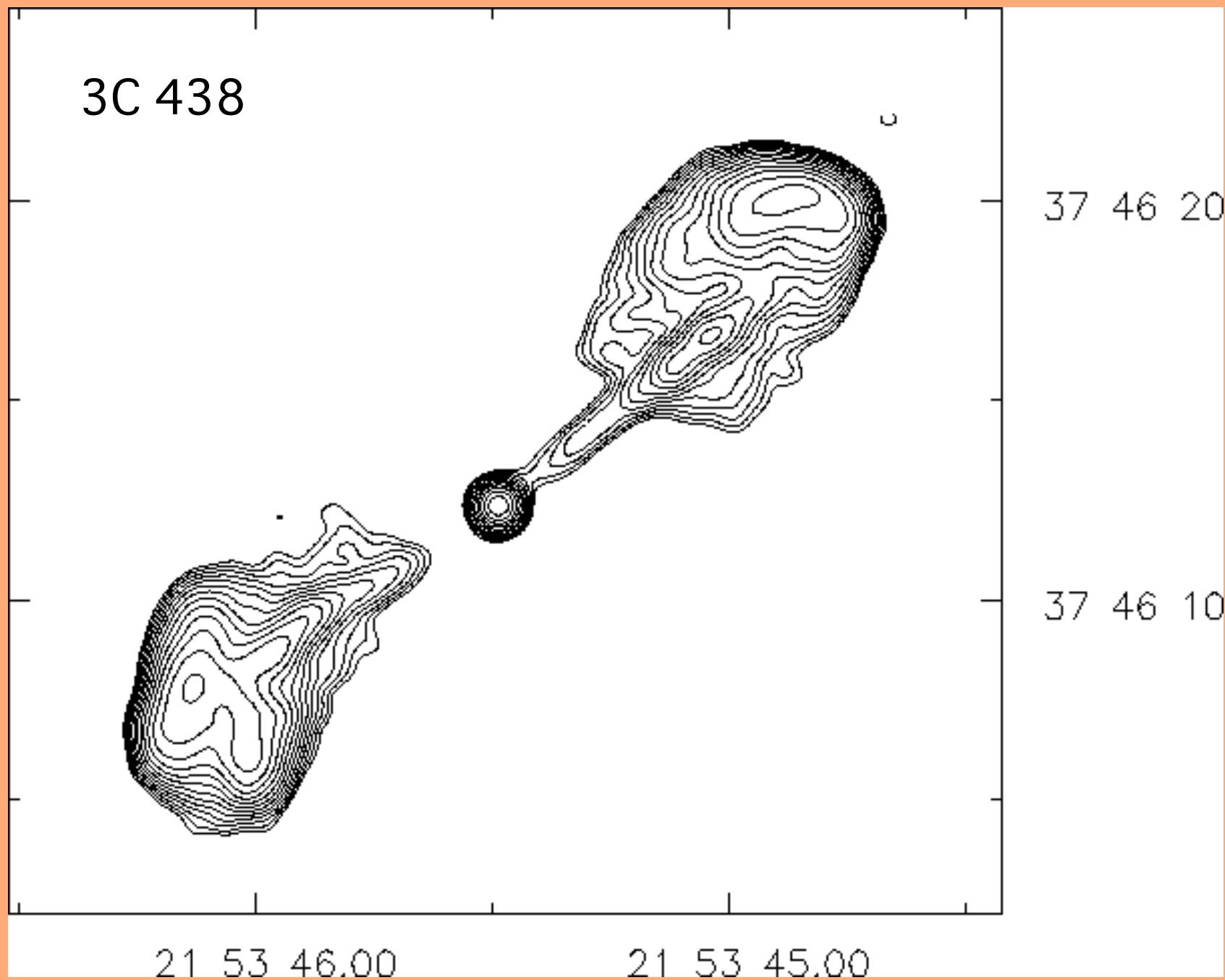


3'  $\approx$  0.6 Mpc (d/0.6 Gpc)

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3C 438





3C 273



75 kpc /  $H_{-17.7}$

# Wide-Field Radio Image of the Galactic Center

$\lambda = 90 \text{ cm}$

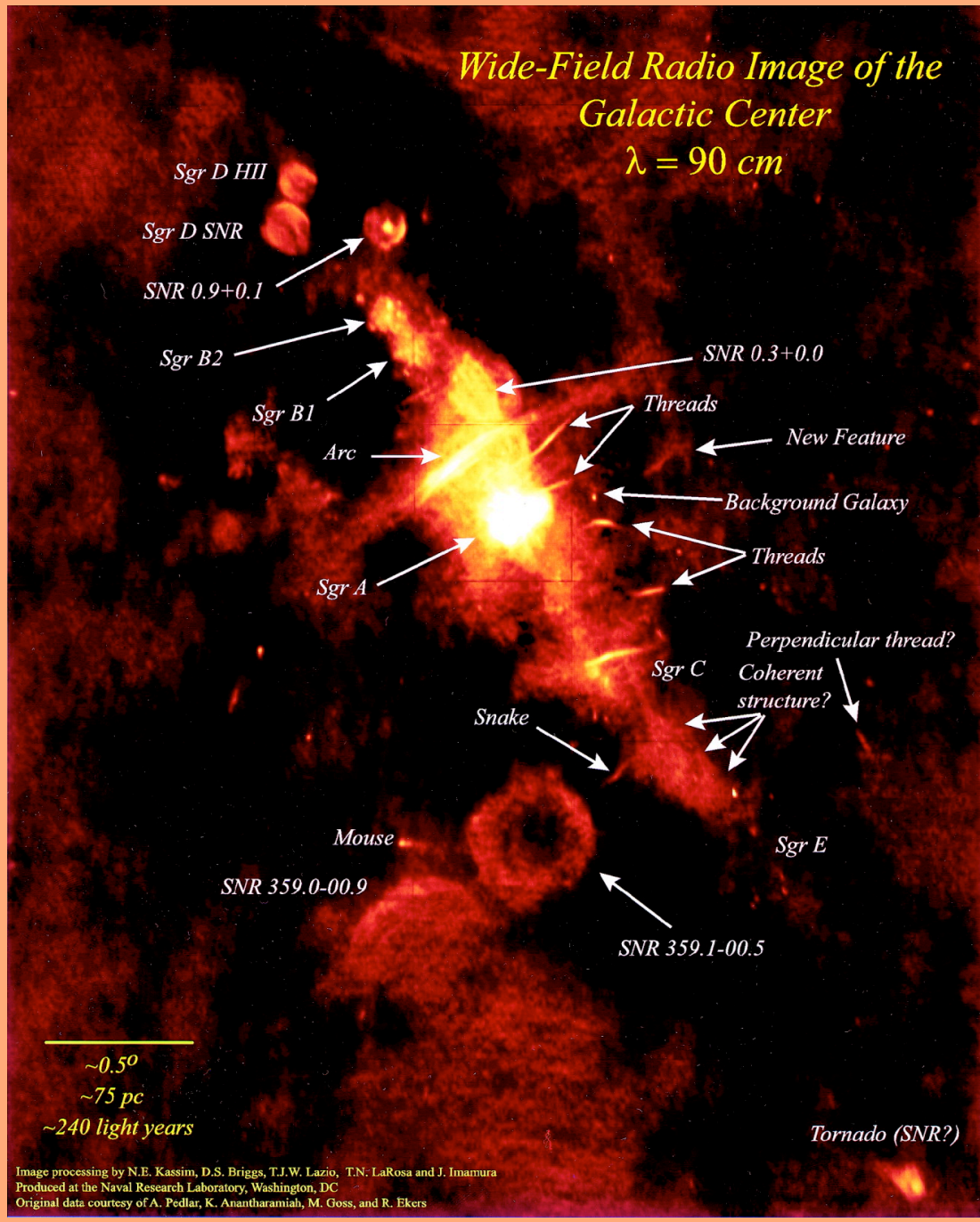
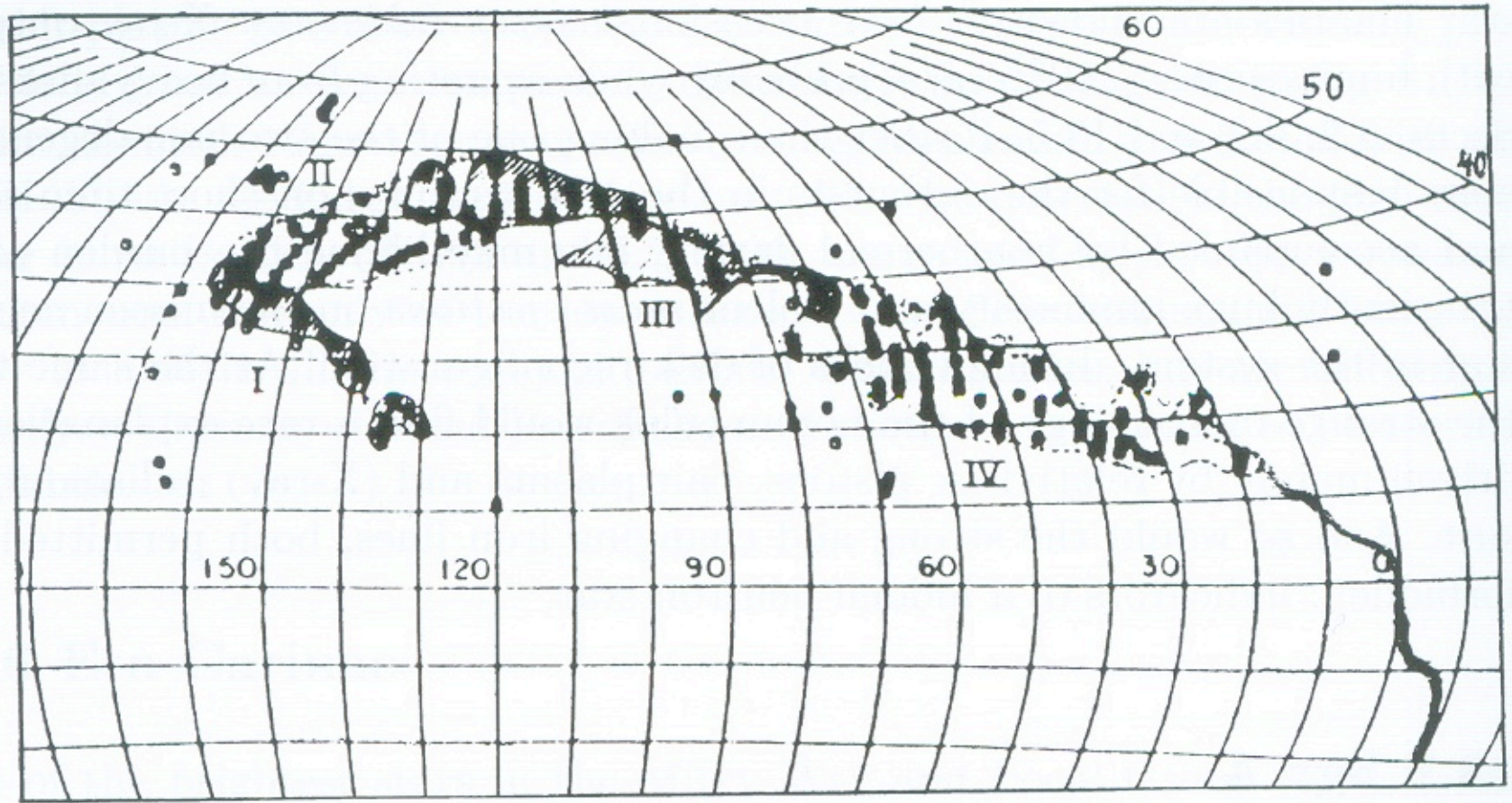
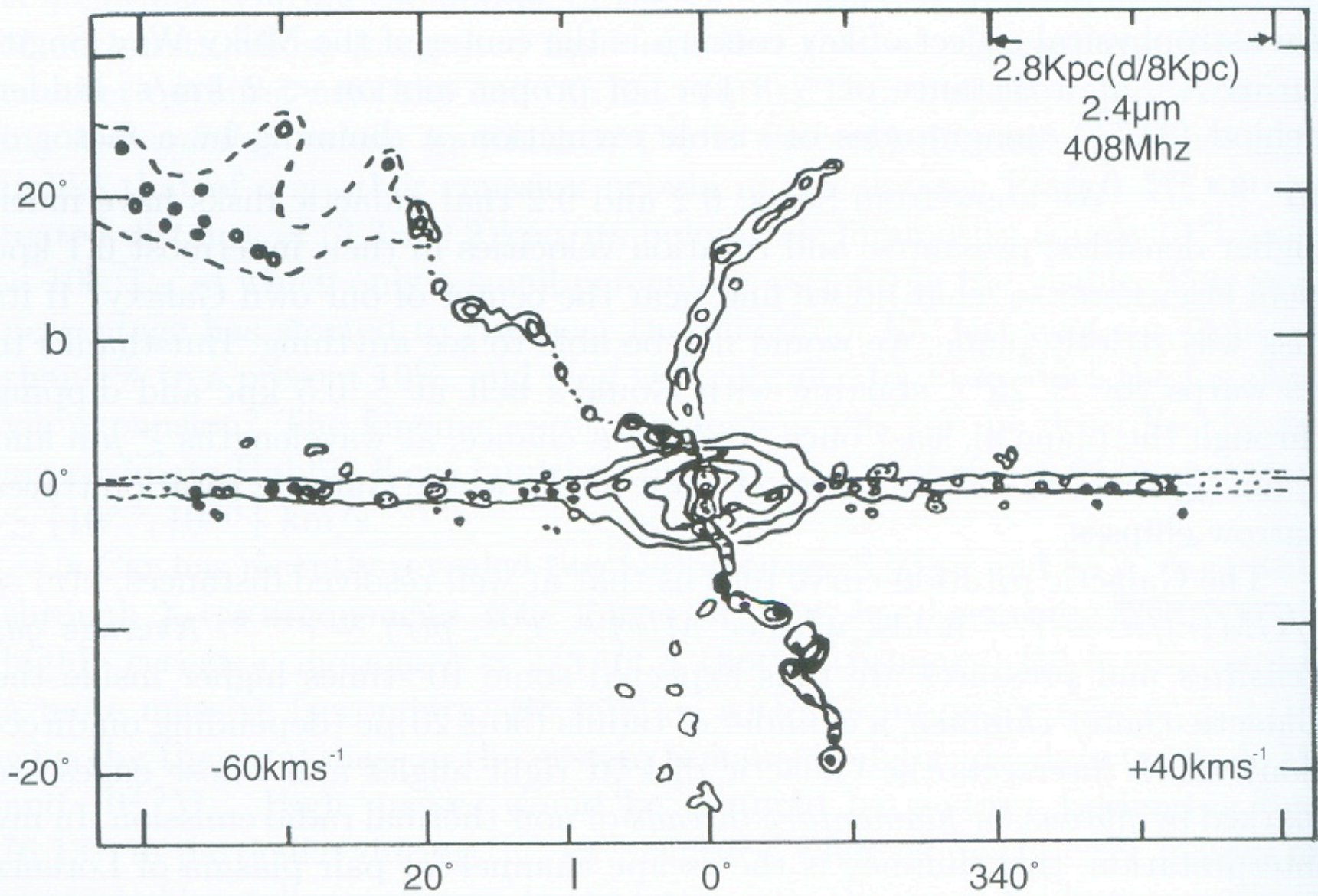
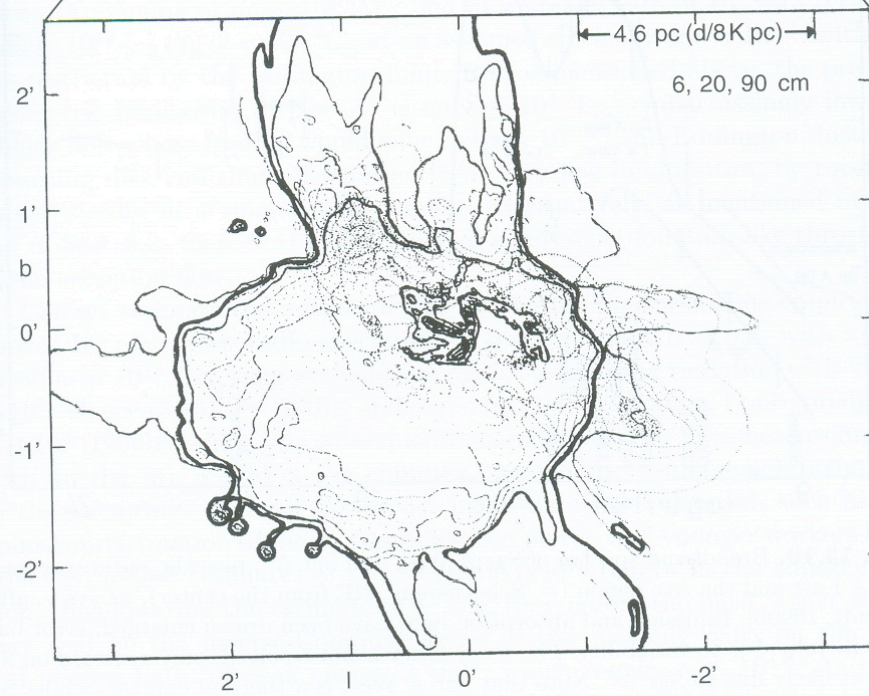
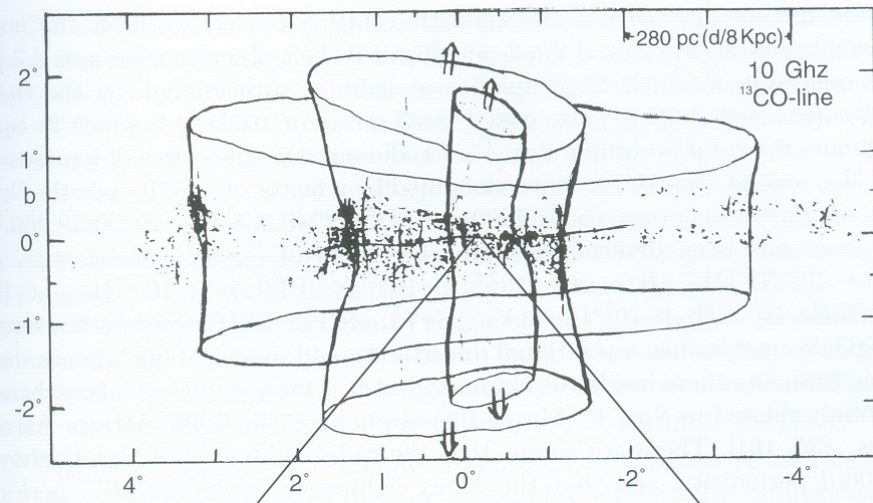


Image processing by N.E. Kassim, D.S. Briggs, T.J.W. Lazio, T.N. LaRosa and J. Imamura  
Produced at the Naval Research Laboratory, Washington, DC  
Original data courtesy of A. Pedlar, K. Anantharamiah, M. Goss, and R. Ekers

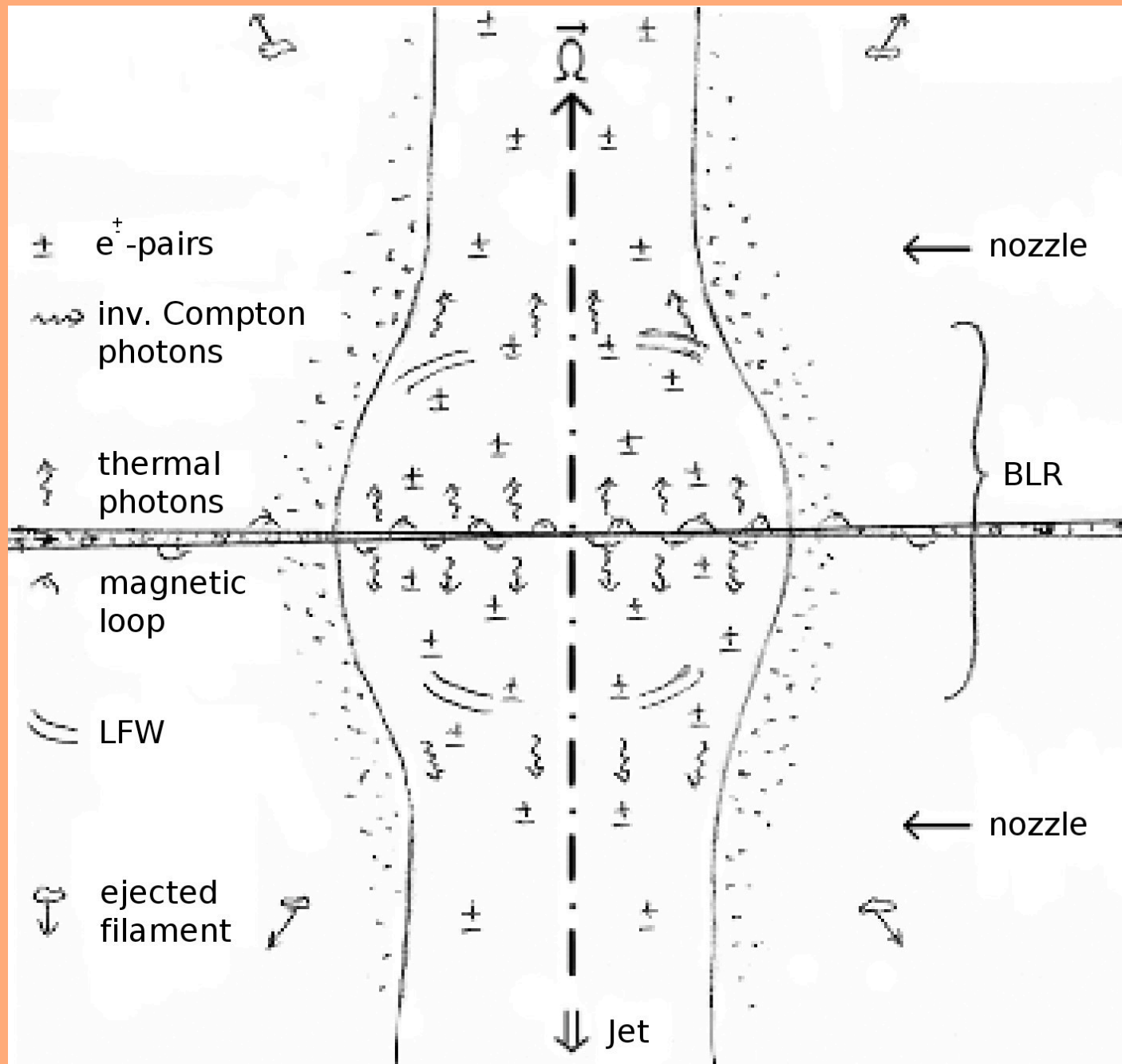






# FORMATION

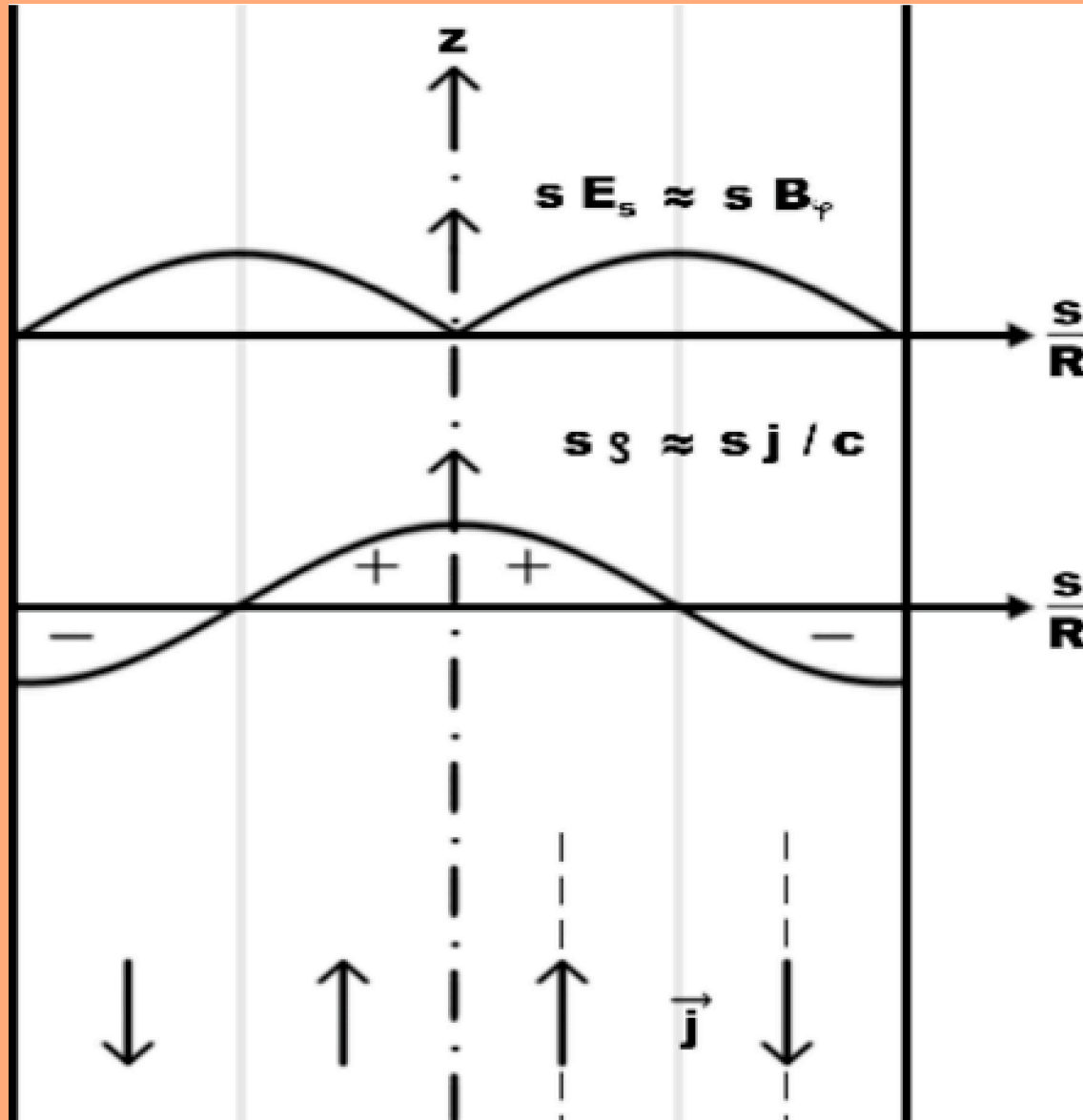
- Relativistic pair plasma created in magnetic reconnections.
- Post-Acceleration of the pair plasma by buoyancy and by Low-Frequency Waves.
- Cooling of escaping pair plasma via thermal photon bath.
- Jet Formation by traversing a self-swept deLaval nozzle.
- On crossing the nozzle, the charges' energy distribution changes from a relativistic Maxwellian to a delta function, via a self-generated (axi-symmetric)  $\mathbf{E} \times \mathbf{B}$ -drift. Repeated focussing of the jet by the inertia of the ambient CJM.



# PROPAGATION

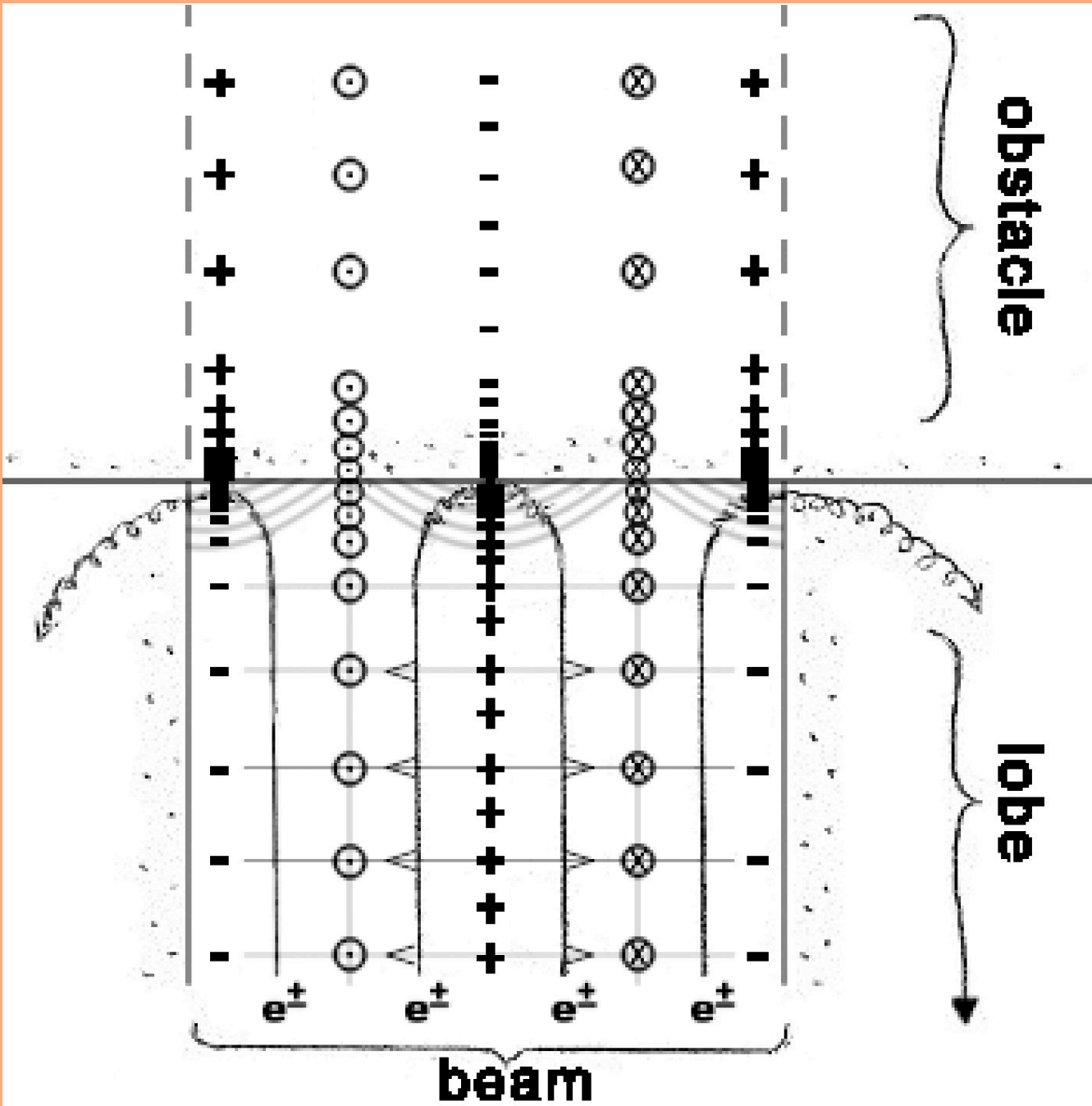
- An axisymmetric approximation can be modelled analytically, with  $\mathbf{E}_{\text{rad}} = \mathbf{B}_{\text{tor}}$ ,  $j \approx \rho c$ ,  $r\rho(r=0) \neq 0$ , with equipartition of energy densities of particles and fields, and with vanishing (synchrotron) radiation, as a radial Fourier expansion.
- An additional longitudinal  $\mathbf{B}$ -field is an option.
- The mono-energetic spectrum of the leptons is stabilized by the  $\mathbf{E} \times \mathbf{B}$ -drift.



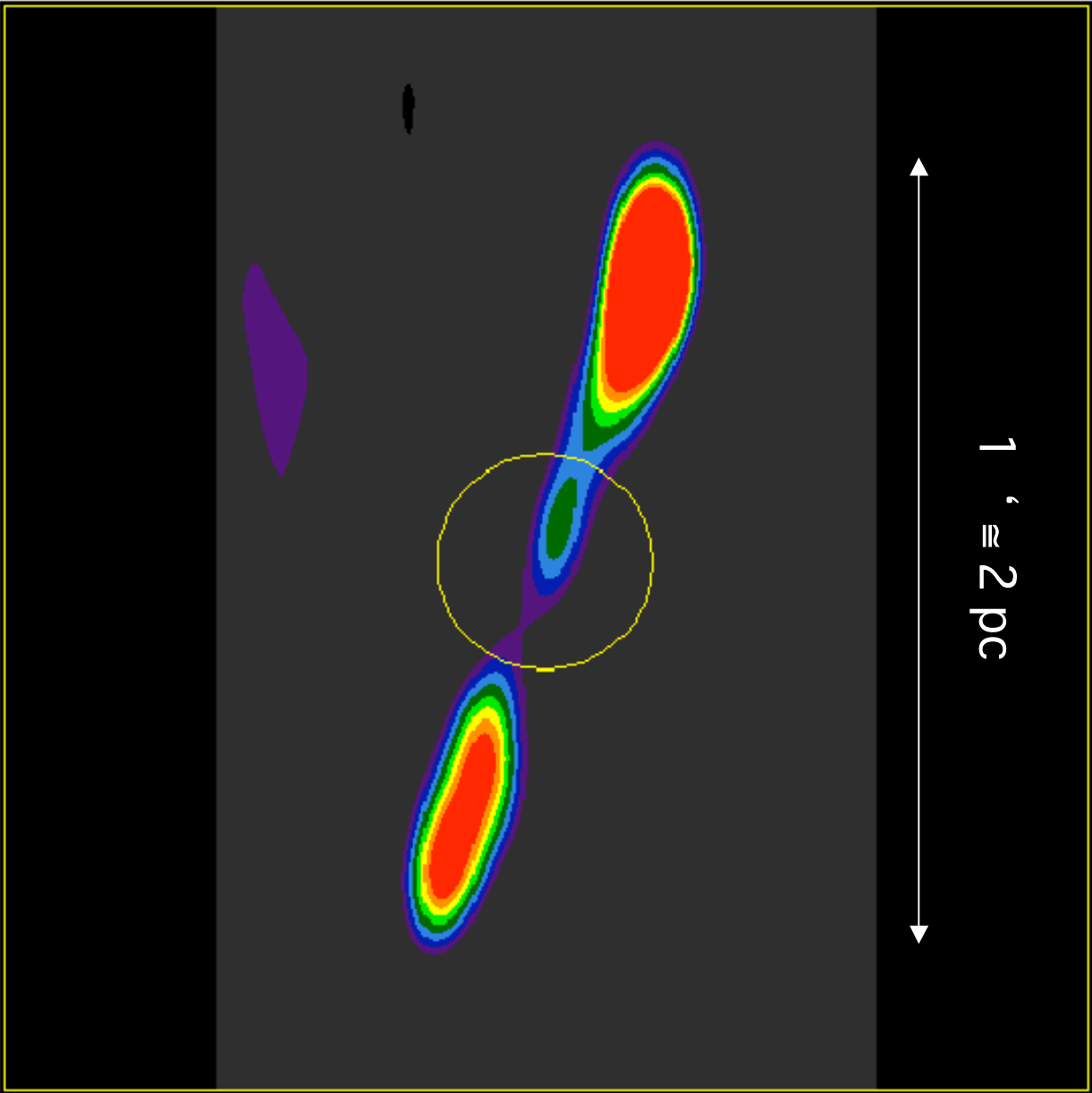


# DISCHARGING

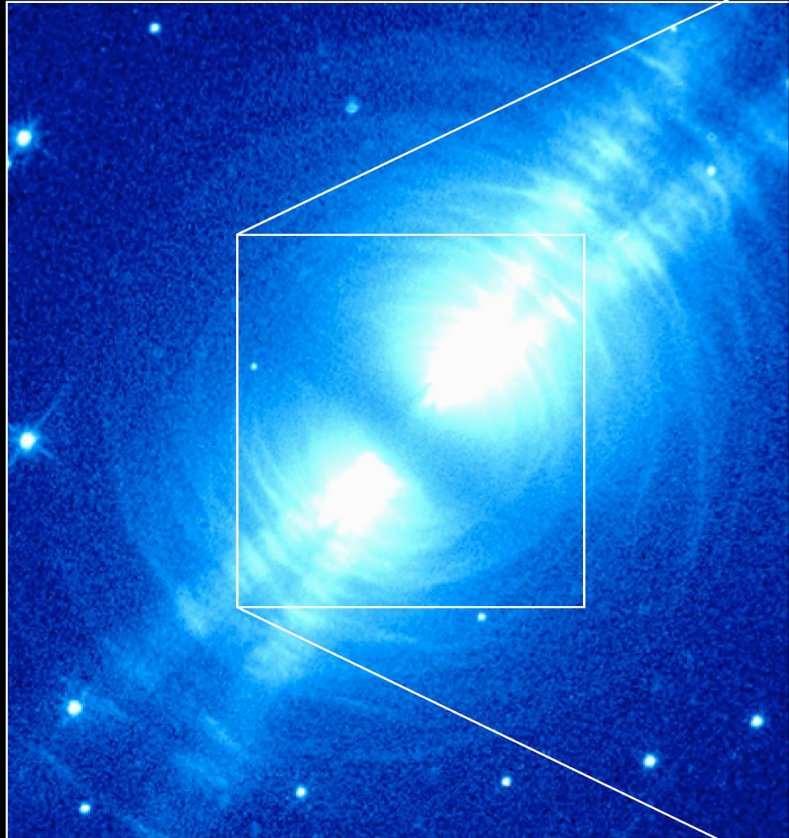
- When a jet encounters (conductive) resistance, mirror charges and mirror currents are induced in it such that the almost relativistic flow is diverted sideways and reflected subsonically, in a gyrating mode, observed as 'knots' and 'head'.
- The compression of the excess charges liberates the huge convected electric potential (between axis and periphery), of order  $e \Phi = 10^{19.5} \text{ eV } \sqrt{L_{44}}$ , and a space-charge limited fall of the pair plasma through it converts its energy distribution into the observed broad power law.



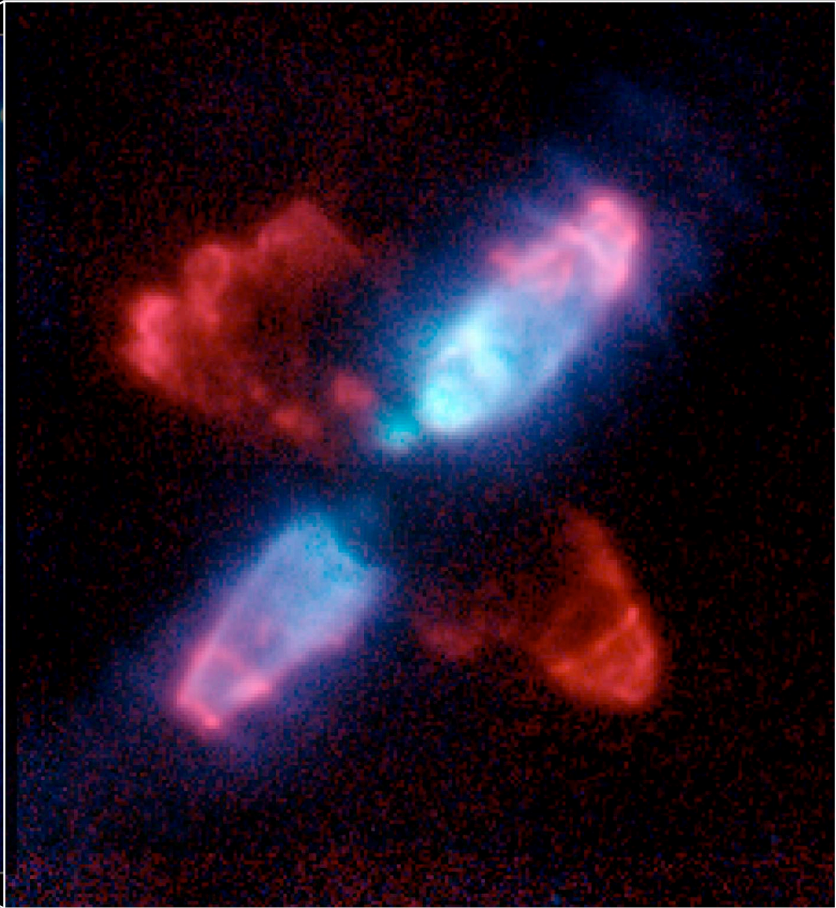
# The Great Annihilator



WFPC2



NICMOS



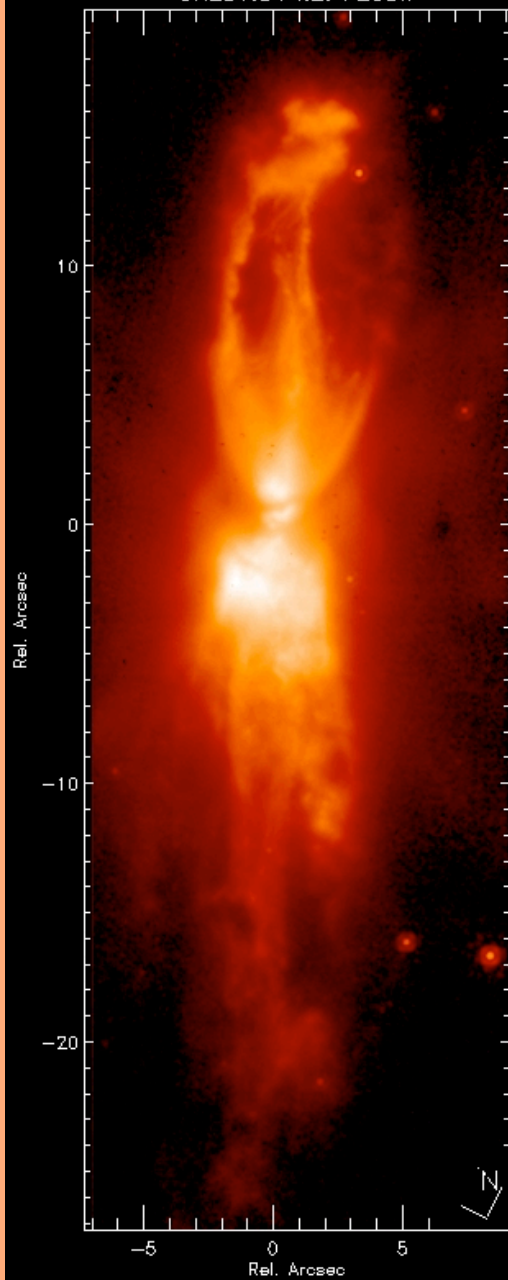
## Egg Nebula

Hubble Space Telescope • WFPC2 • NICMOS

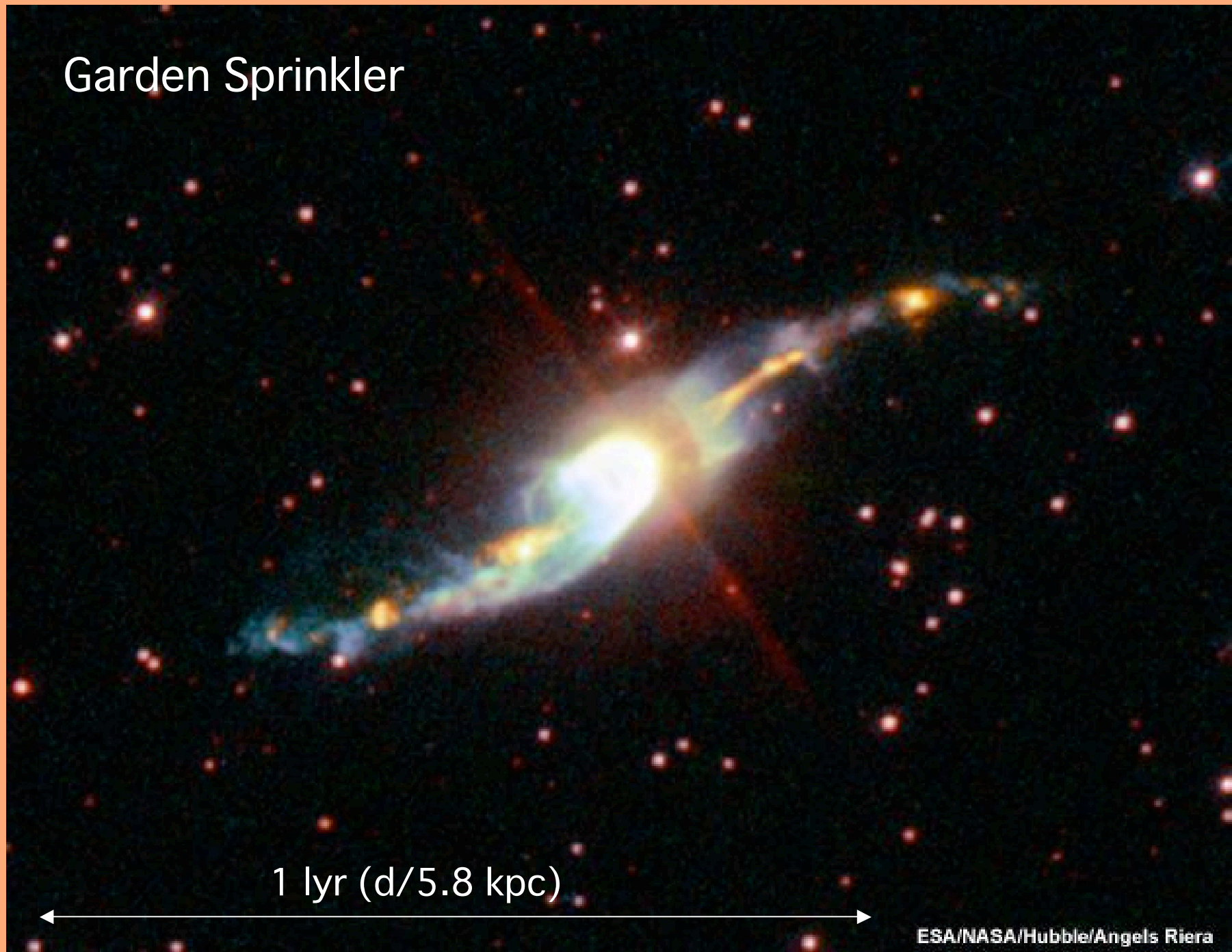
PRC97-11 • ST ScI OPO • May 12, 1997 • R. Thompson (University of Arizona), D. Hines (University of Arizona), R. Sahai (JPL) and NASA

$d = 1 \text{ kpc}$  ,  $\varnothing \approx 25''$   $\rho$   
0.2 ly

OH231.8+4.2: F205W



# Garden Sprinkler

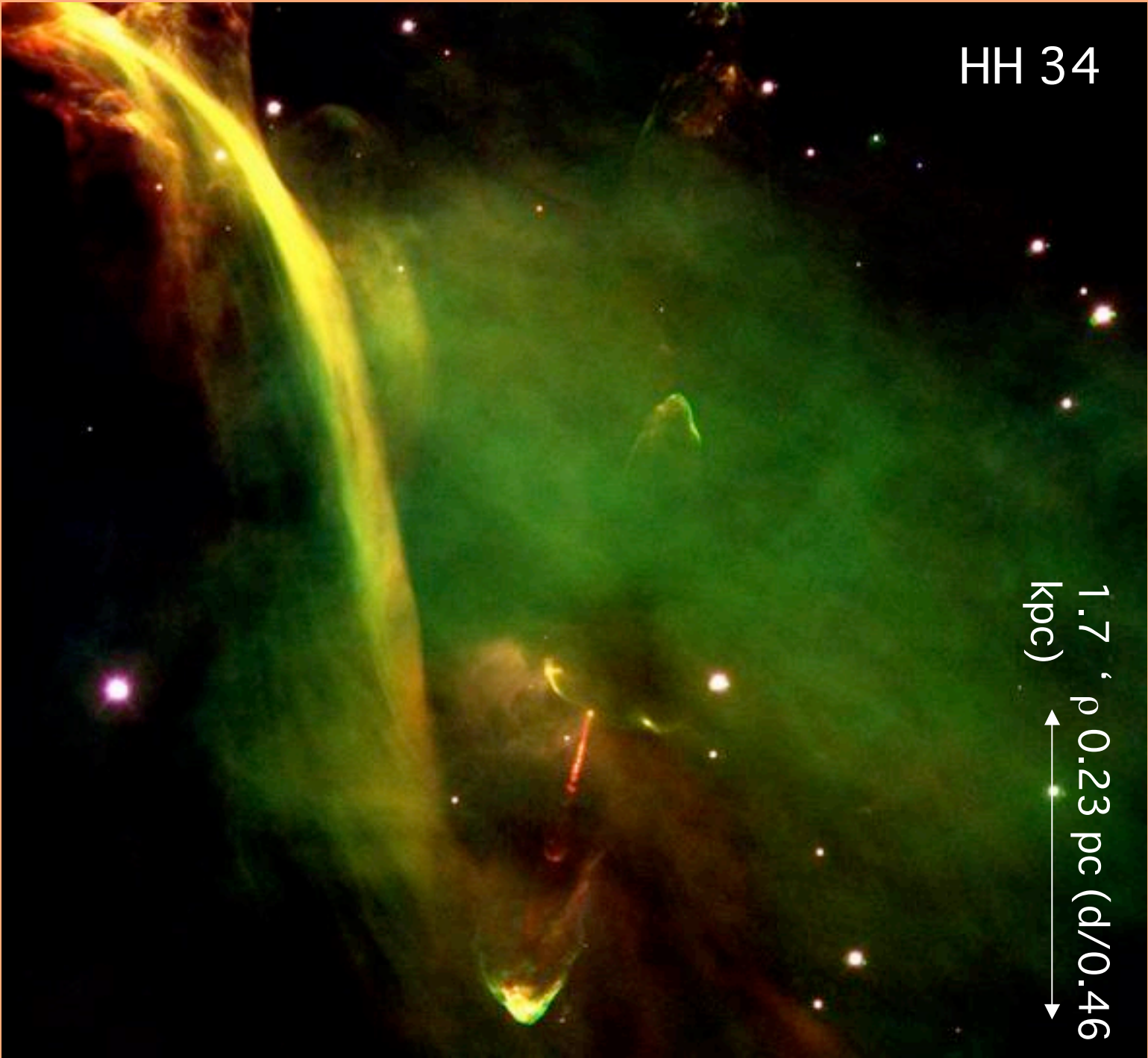


1 lyr (d/5.8 kpc)

ESA/NASA/Hubble/Angels Riera

HH 34

1.7'  $\rho$  0.23 pc (d/0.46  
kpc)  $\longleftrightarrow$





HH 30

February 1994

January 1995

