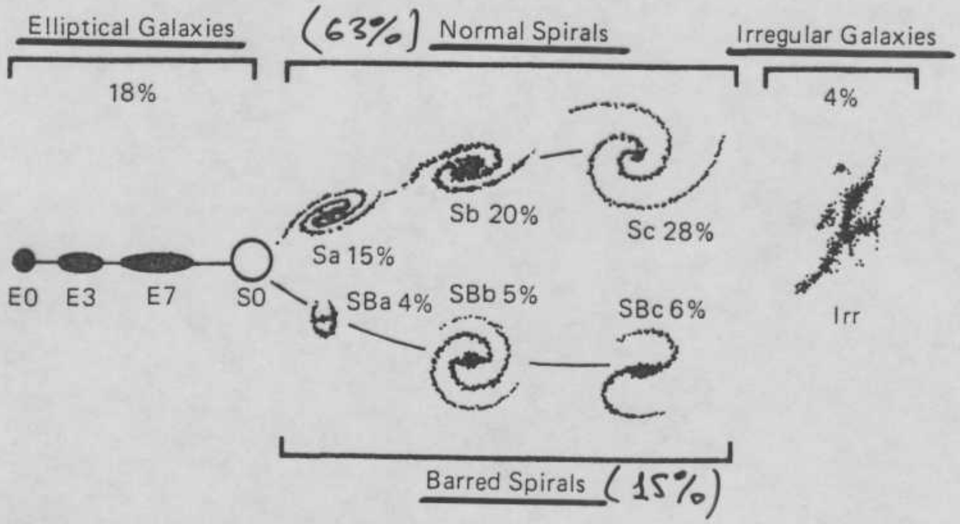


Properties of the Galaxy

Type of galaxy:
- Hubble–van den Bergh system: Sb(−Sb$^+$)I–II
- de Vaucouleur's system: SAB(rs)bc II
- Morgan's system: gkS 7

M_v (mag): −20.5
Diameter: 23 kpc
(isophote: 25.0 mag (B) arcsec^{-2})
Period of rotation: 2.5×10^8 yr
Mass:
- Total mass: $1.8 \times 10^{11}\ M_\odot$
- Gas: $8 \times 10^9\ M_\odot$

Age: 1.2×10^{10} yr
Density in solar neighborhood:
- Stars: $0.05\ M_\odot\ \mathrm{pc}^{-3}$
- Total known: $0.08\ M_\odot\ \mathrm{pc}^{-3}$

Galactic nucleus:
- $R < 0.4\ \mathrm{pc} \approx 5 \times 10^6\ M_\odot$
- $R < 150\ \mathrm{pc} \approx 1 \times 10^9\ M_\odot$

Central bulge ($R < 2.5$ kpc): $\approx 4 \times 10^{10}\ M_\odot$

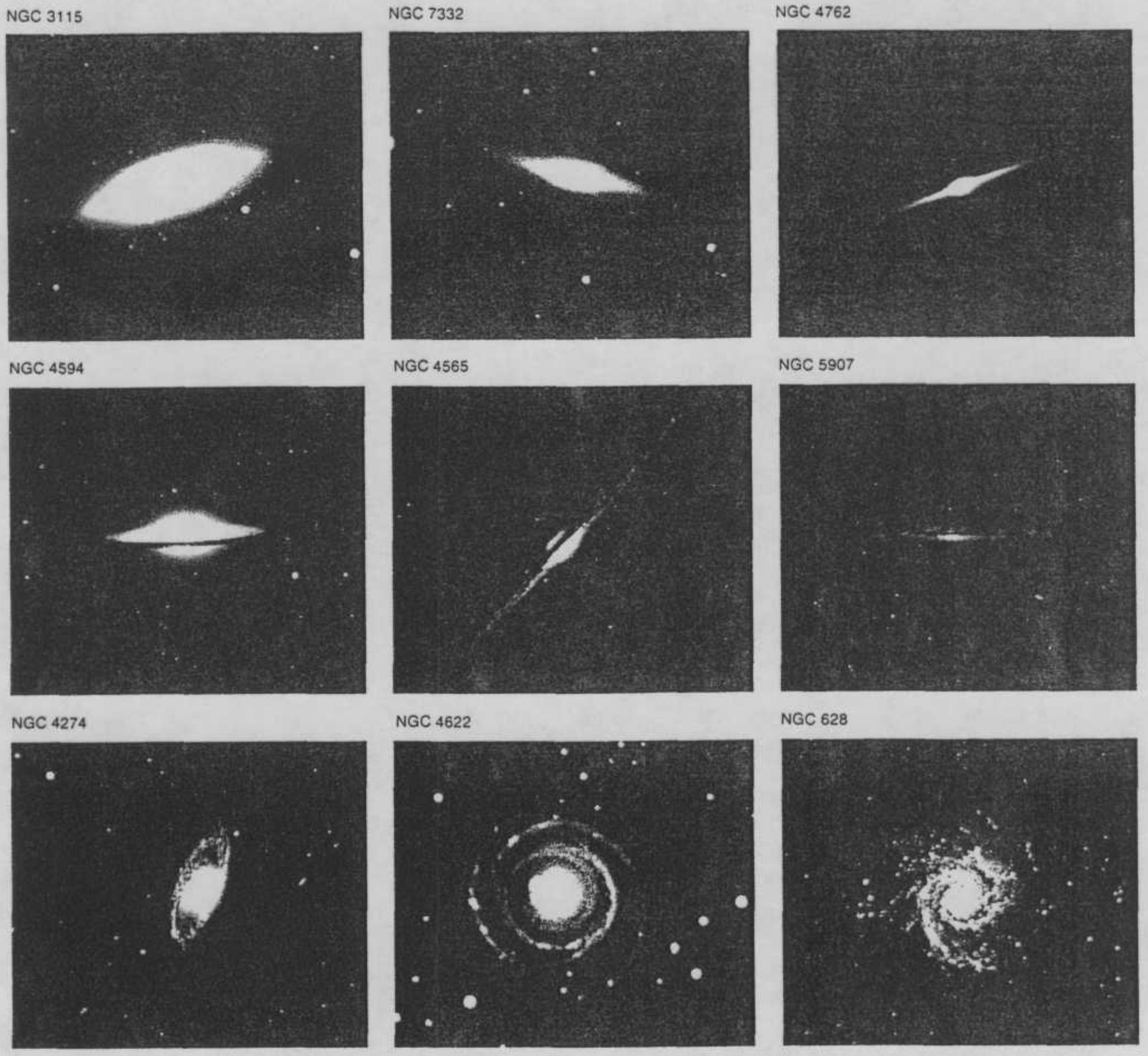
Luminosity of the galaxy:		*Energy density in the galaxy:*	
Radio	3×10^{38} erg s^{-1}	Starlight	0.7×10^{-12} erg cm^{-3}
Infrared	3×10^{41}	Turbulent gas	0.5×10^{-12}
Optical	3×10^{43}	Cosmic rays	2×10^{-12}
X-ray	$10^{39} - 10^{40}$	Magnetic field	2×10^{-12}
γ-ray (> 100 MeV)	5×10^{38}	2.7 K radiation	0.4×10^{-12}

Mass–luminosity ratio: M/L_{bol} (solar units) ≈ 10
Stellar radiation emission (solar neighborhood):
- $1.5 \times 10^{-3} (M_{\mathrm{bol}} = 0)$ stars pc^{-3}
- 1.5×10^{-23} erg cm^{-3} s^{-1}

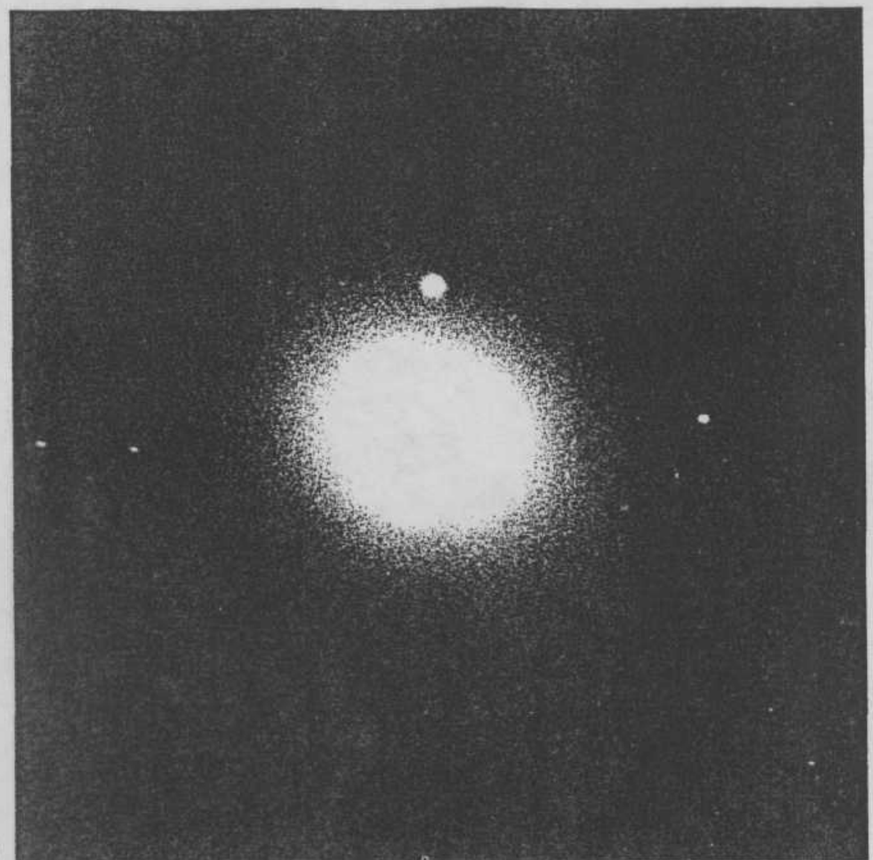
Stellar luminous radiation emission (solar neighborhood):
- $6.7 \times 10^{-4} (M_v = 0)$ stars pc^{-3}

Distance of the Sun from the galactic center:
- 8.7 ± 0.6 kpc (IAU, 1985)
- 7.1 ± 1.2 kpc (courtesy of M. Reid, Harvard/Smithsonian)

Height of Sun above galactic disk: 8 pc



DISK GALAXIES can be divided into two broad categories: spiral systems and SO systems. Both kinds of galaxy have a central bulge and a surrounding disk. The disks of spiral galaxies have visually prominent arms because they are studded with complexes of bright, newly formed stars. The disks of SO galaxies, in contrast, are smooth, show no spiral structure and are devoid of young stars. The three photographs in the top row depict SO systems viewed nearly edge on, arranged in order of the decreasing prominence of their bulge with respect to their disk. No evidence of recent star formation is visible. The photographs in the middle row show three galaxies of the spiral type, also seen edge on and in order of decreasing bulge-to-disk ratio. The galaxies in the bottom row illustrate the probable face-on appearance of spiral galaxies in the middle row. The bright knots in the spiral arms of the galaxies represent newly formed stellar complexes.



GIANT ELLIPTICAL GALAXY NGC 4472, representative of systems that have no disk, is presumed to be spheroidal in shape. Like SO galaxies, it is entirely lacking in young stars. Such giant galaxies have a mass about 10^{12} times the mass of the sun, which makes them five or 10 times as massive as our own large spiral galaxy. NGC 4472 is 60 million light-years away.

Globular Cluster NGC 6093

Hubble Heritage

PRC99-26 • Space Telescope Science Institute • Hubble Heritage Team (AURA/STScI/NASA)

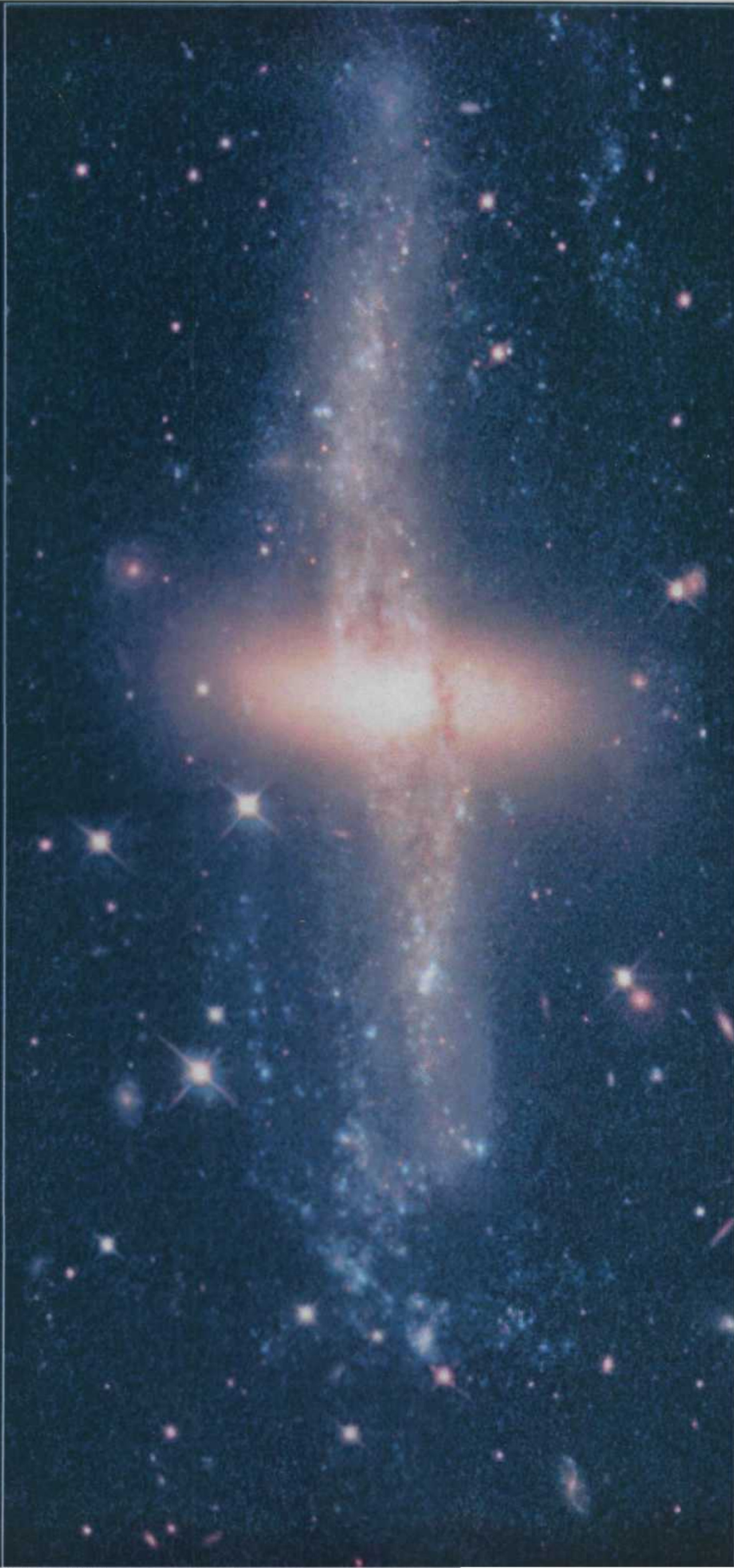
887

arred Spiral Galaxy NGC 1365 **HST • W**

ASA and M. Carollo (Columbia University) • STScI-PRC99-34a

(89)

Polar-Ring
Galaxy
NGC 4650A

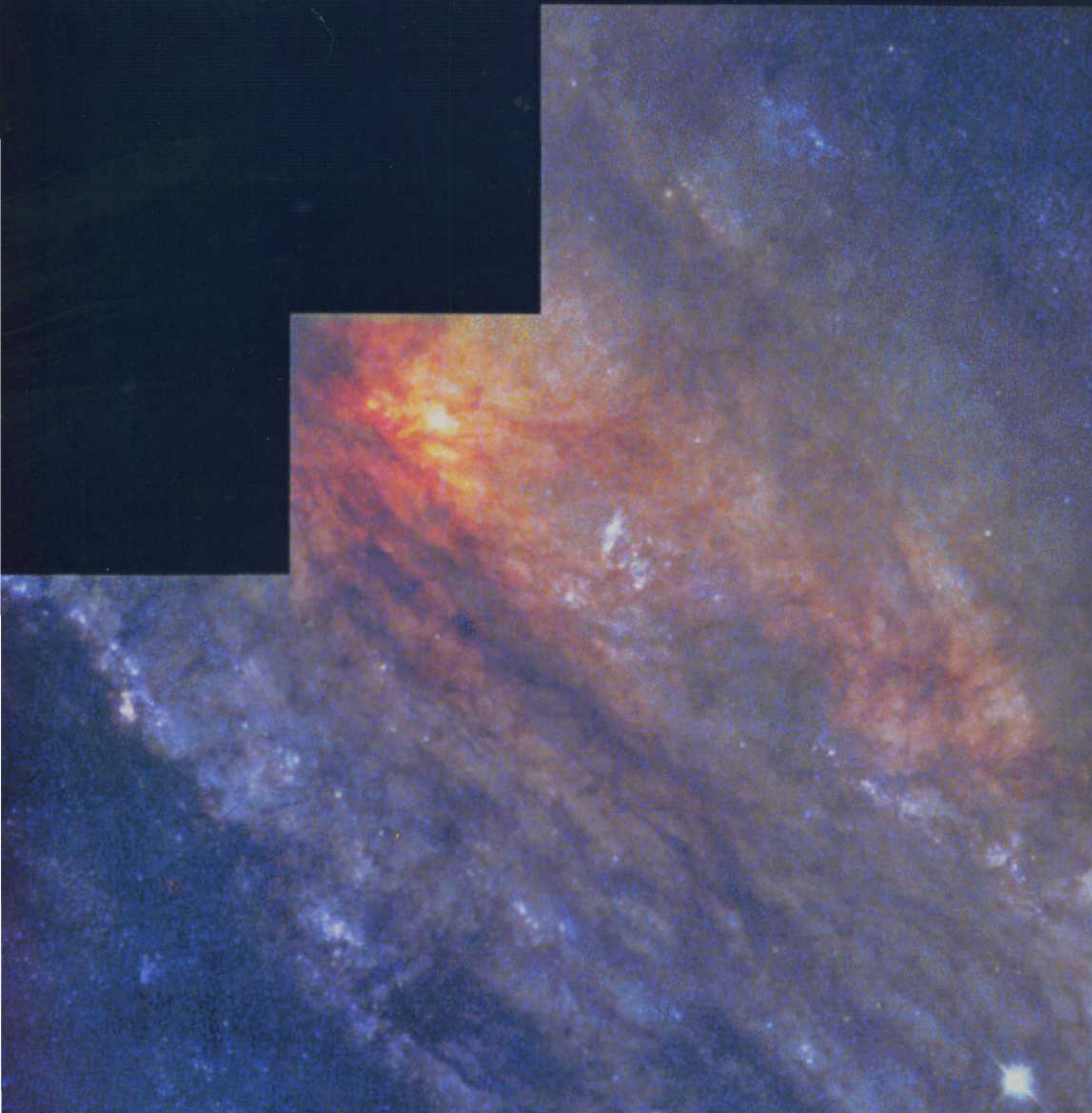


PRC99-12

Space Telescope
Science Institute

Hubble Heritage Team
(AURA/STScI/NASA)

Hubble
Heritage



Galaxy NGC 253

Hubble Heritage

PRC98-42 • Space Telescope Science Institute • Hubble Heritage Team

Квазары и микроквазары. (К, μК)

Квазары: $L \sim 10^{47}$ эрг/с $= 10^{13} \times L_\odot$, $z = \frac{\Delta\lambda}{\lambda} \simeq 0.2 \div 2.5$.

(Шмидт, 1963г.) $(v \simeq c)$

- изменение яркости, $\tau \simeq 1$ часа $\Rightarrow \ell \simeq 10^9$ km
- радиоизлучение, ИК, —"—, X-ray, γ-излучение
  $\downarrow$
  67 Гу
- обнаружение струй.

Микроквазары: $L \sim L_\odot$, наша галактика.

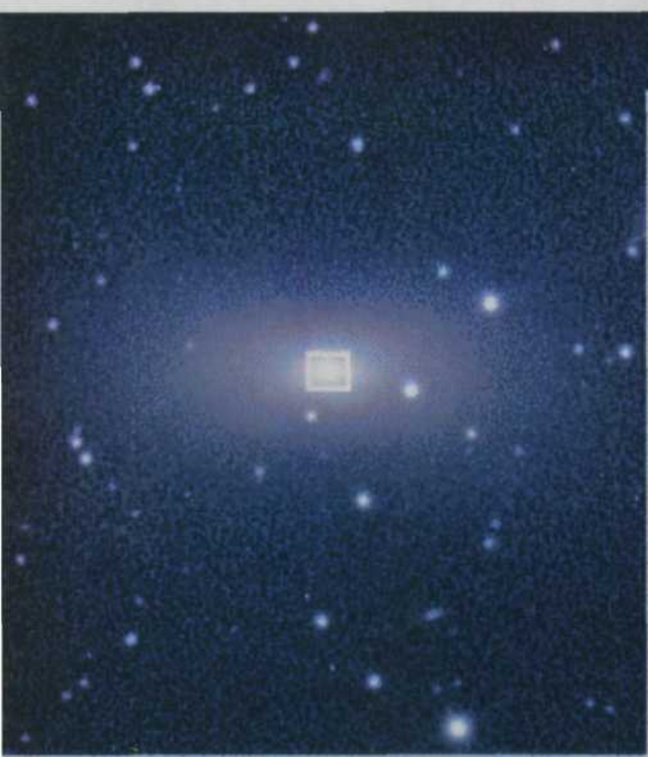
(Mirabel et al, 1992) $(v \simeq c)$

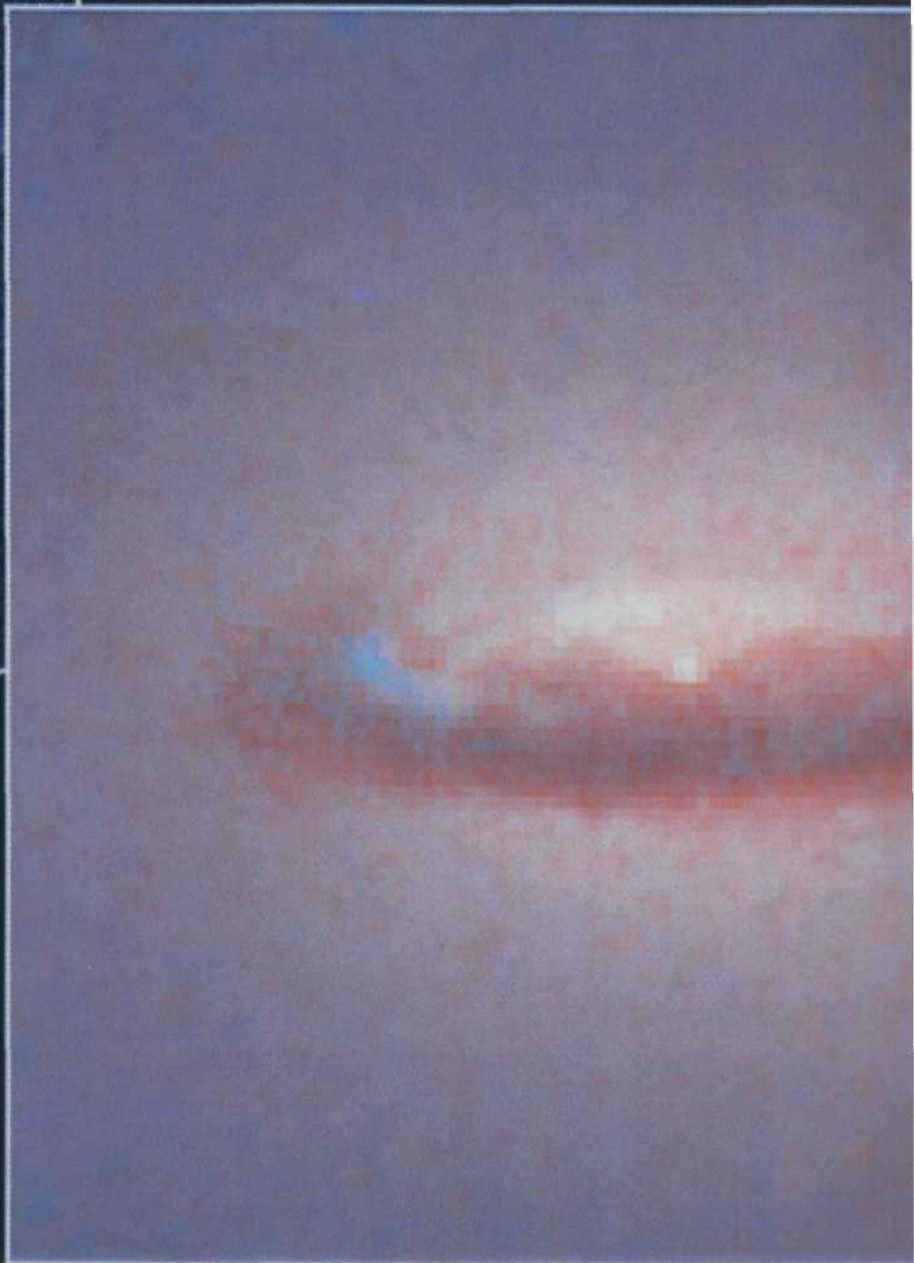
Источник энергии?

К: Чёрная дыра с $M \simeq 10^7 \div 10^9\, M_\odot$

μК: Черная дыра с $M \simeq M_\odot$


NOAO
HST
WFPC2
PRC98-14a • ST ScI OPO • May 14, 1998 • E. Sch





round

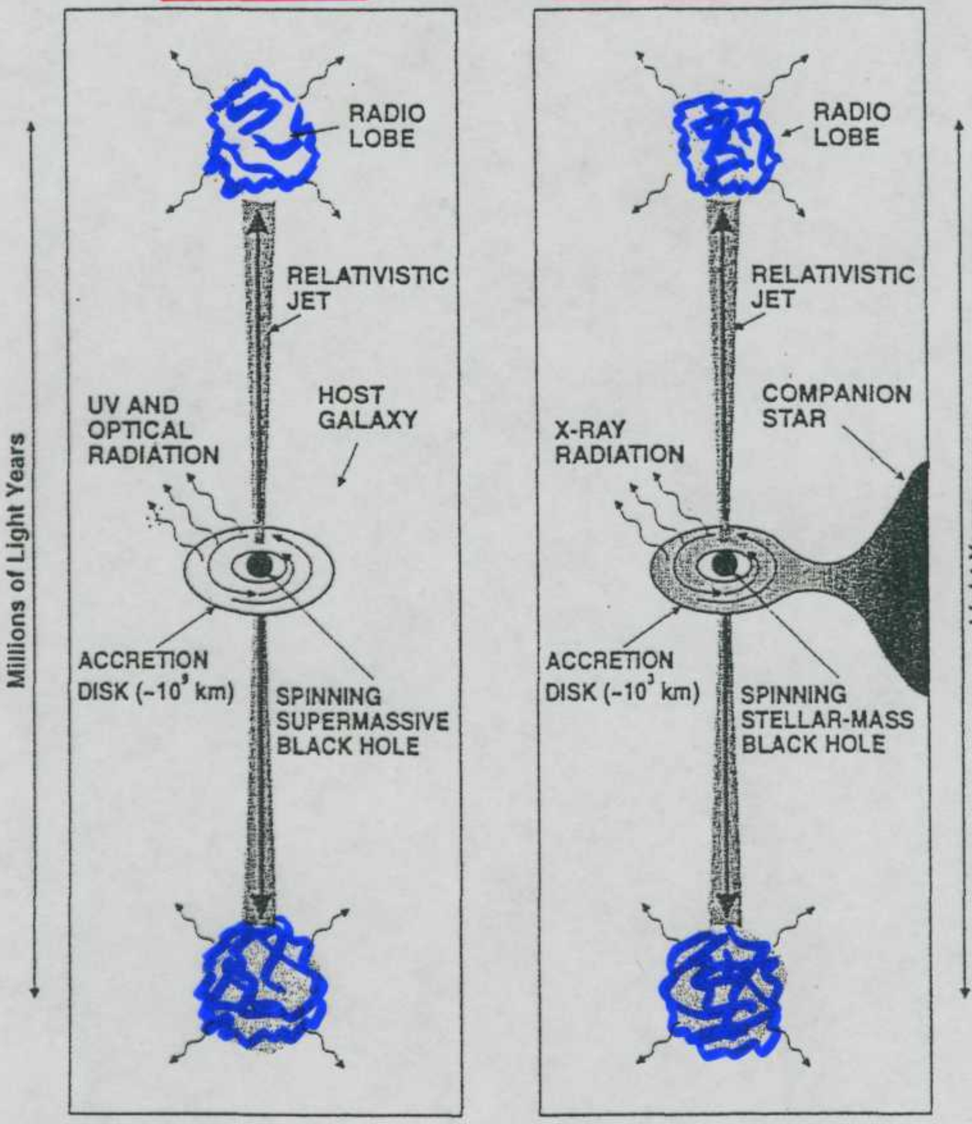
sk in Galaxy NGC 7052

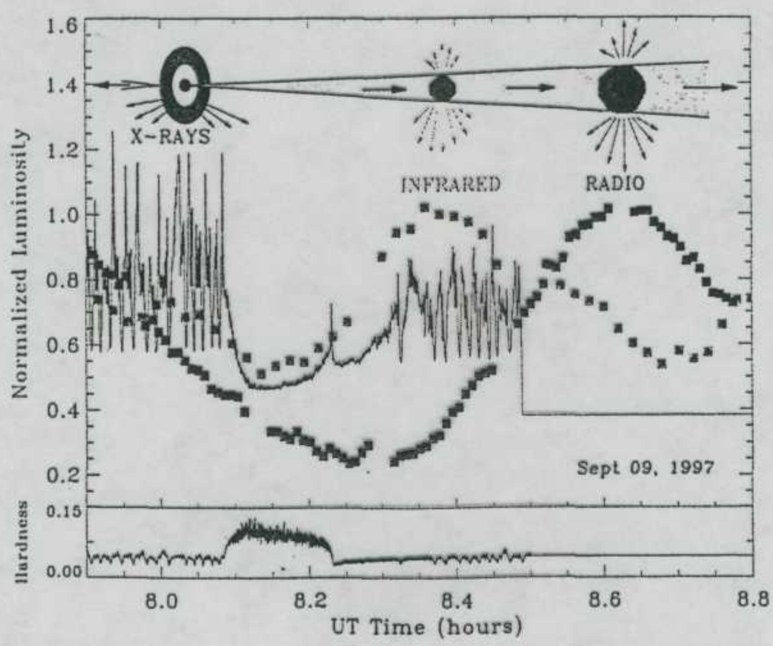
C98-22 • June 18, 1998 • ST ScI OPO

P. van der Marel (ST ScI), F. C. van den Bosch (University of Washington

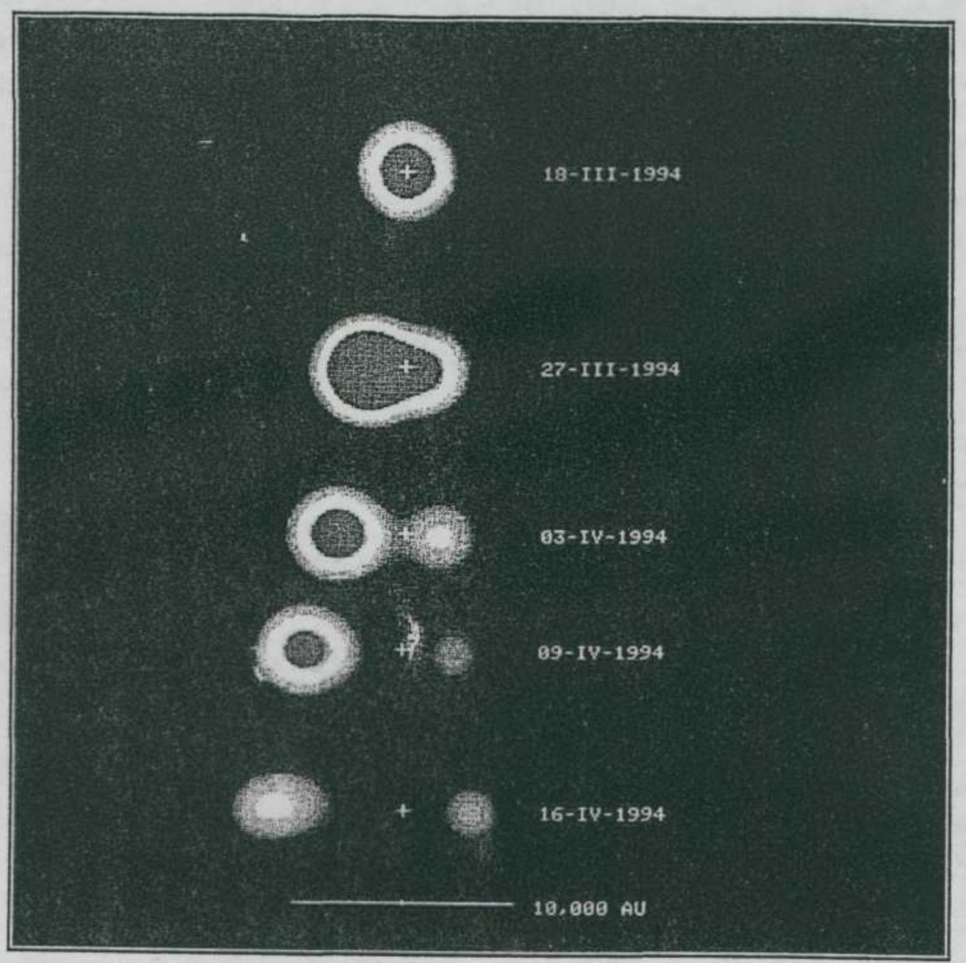

HST • WFPC2
ore of Galaxy NGC4261
C95-47 • ST ScI OPO • December 4, 1995
Ford and L. Ferrarese (JHU), NASA

QUASAR MICROQUASAR





first μK : GRS 1915+105



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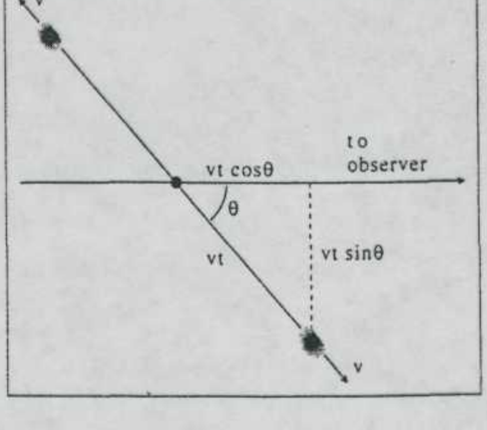
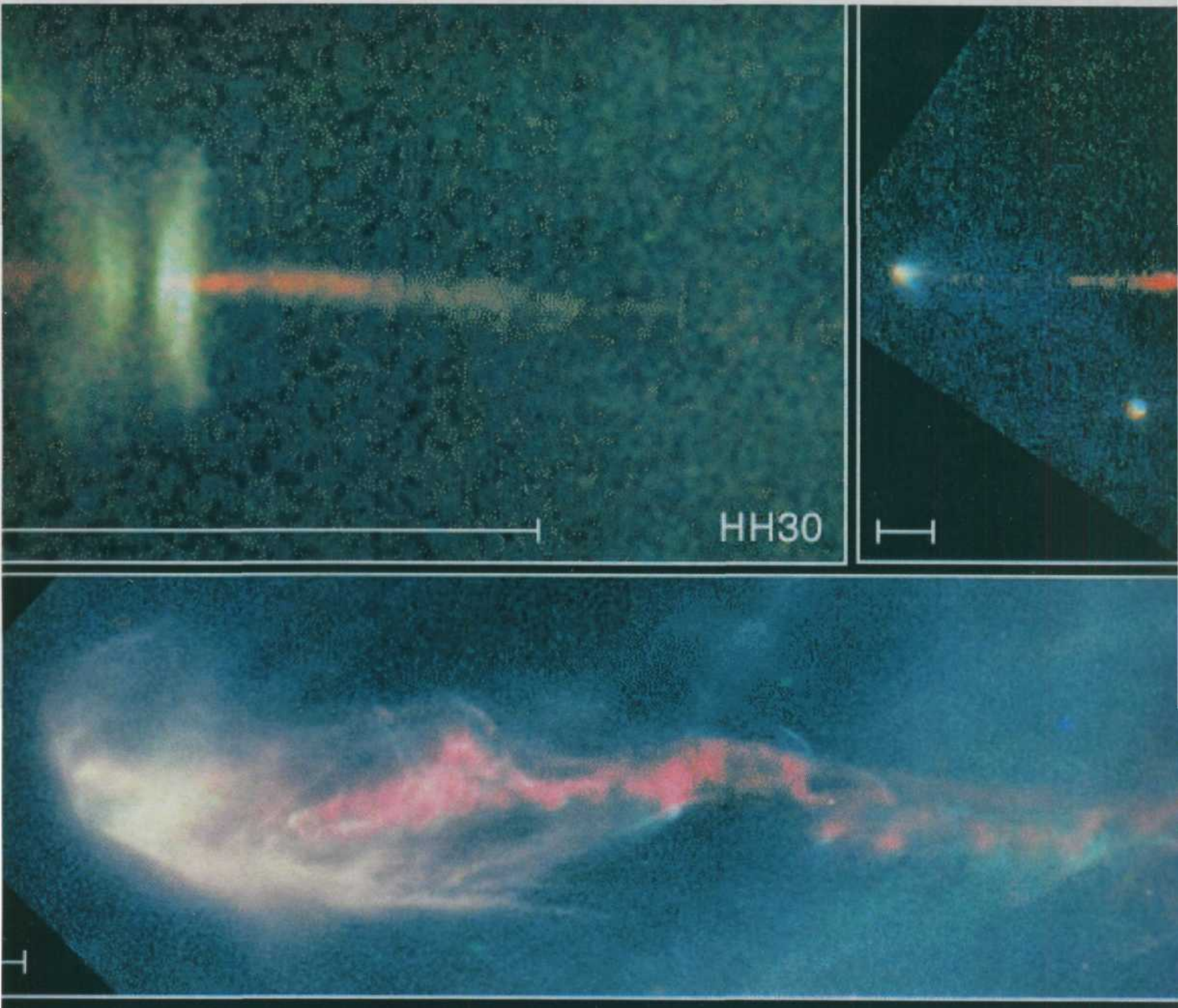
$\lambda = 3.5$ см; $D = 4 \cdot 10^4$ св. лет.



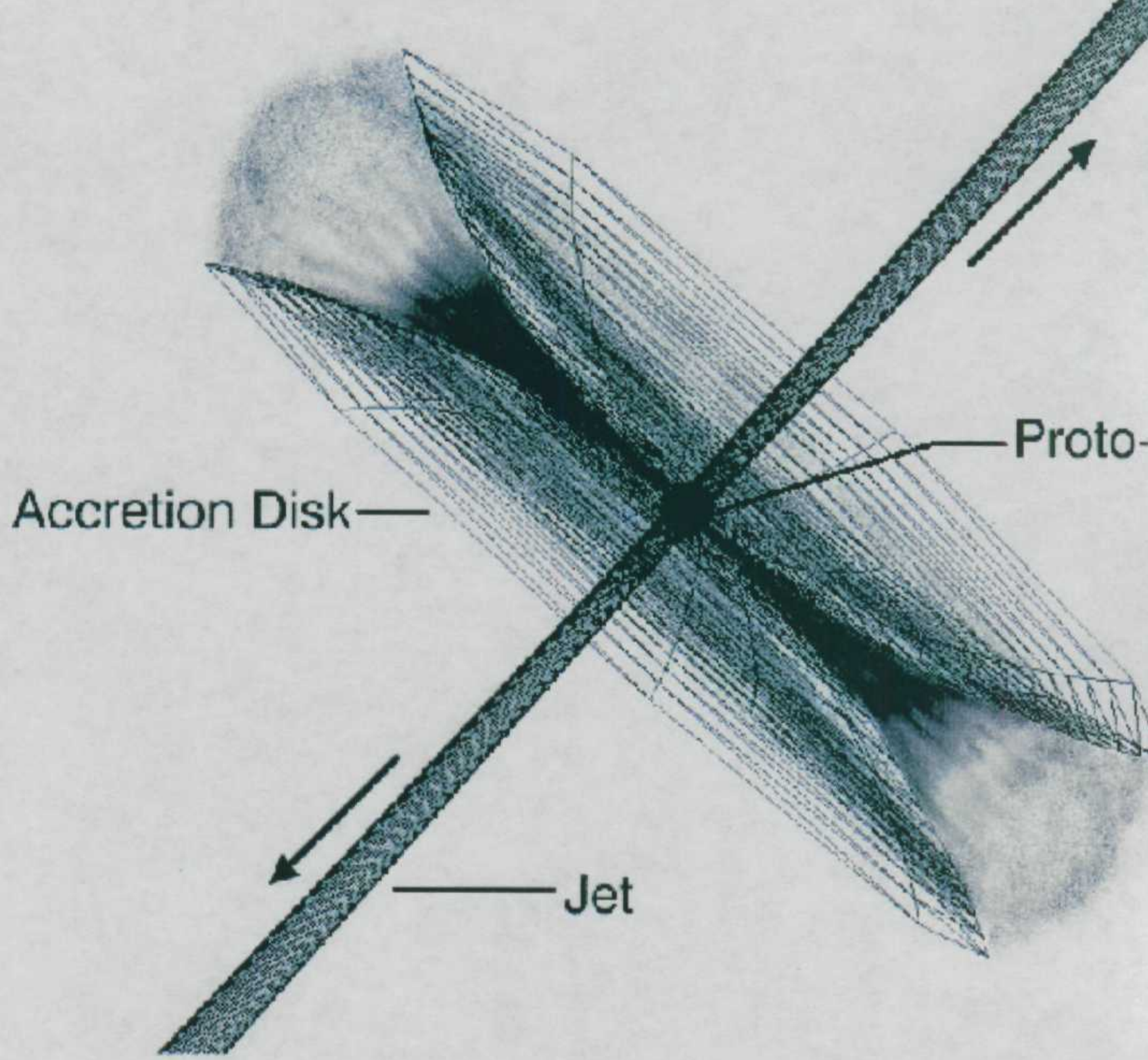


ets from Young Stars

RC95-24a · ST ScI OPO · June 6, 1995

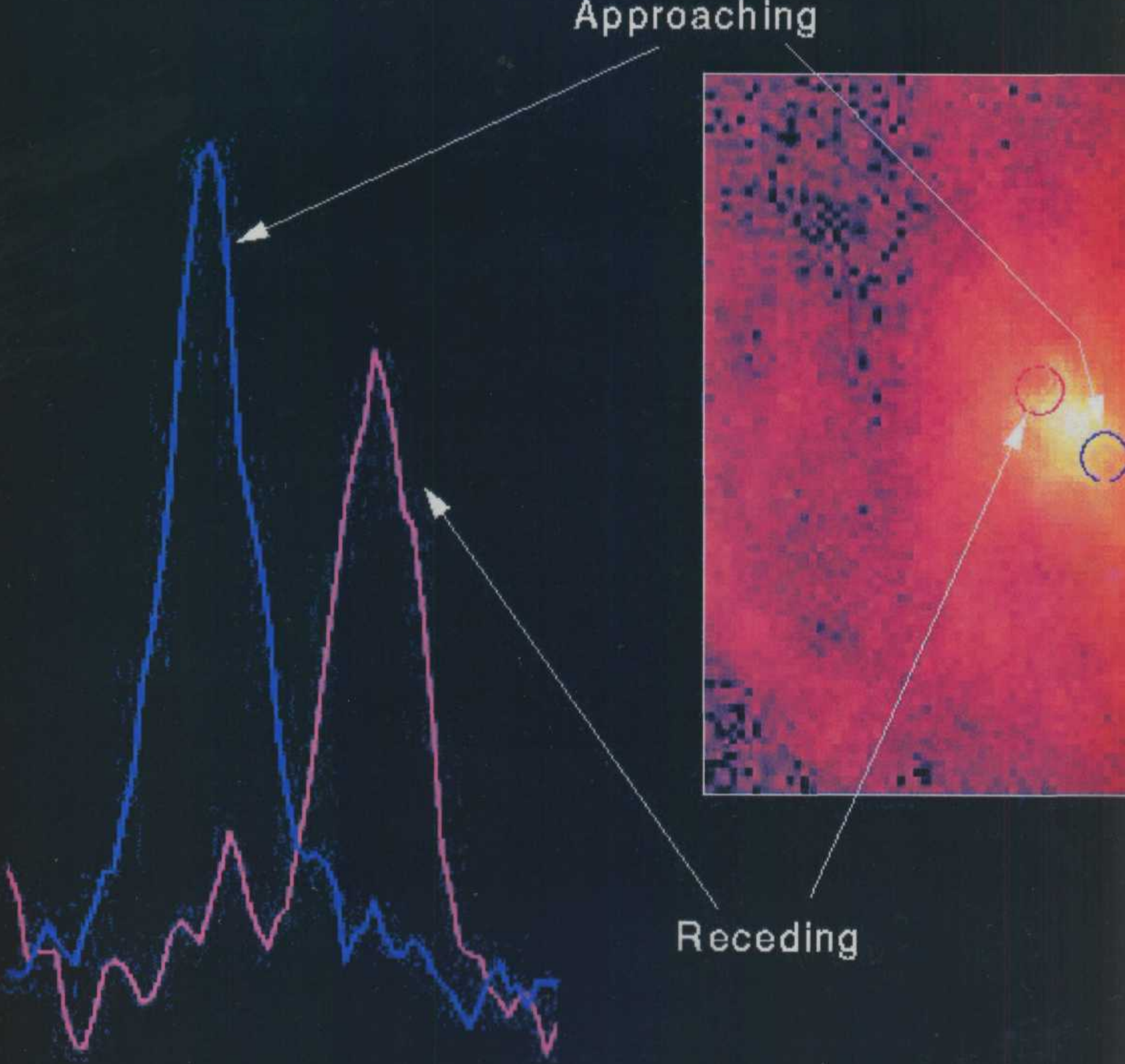
Burrows (ST ScI), J. Hester (AZ State U.), J. Morse (ST ScI), NASA

Diagram of HH 30 Circumstellar D



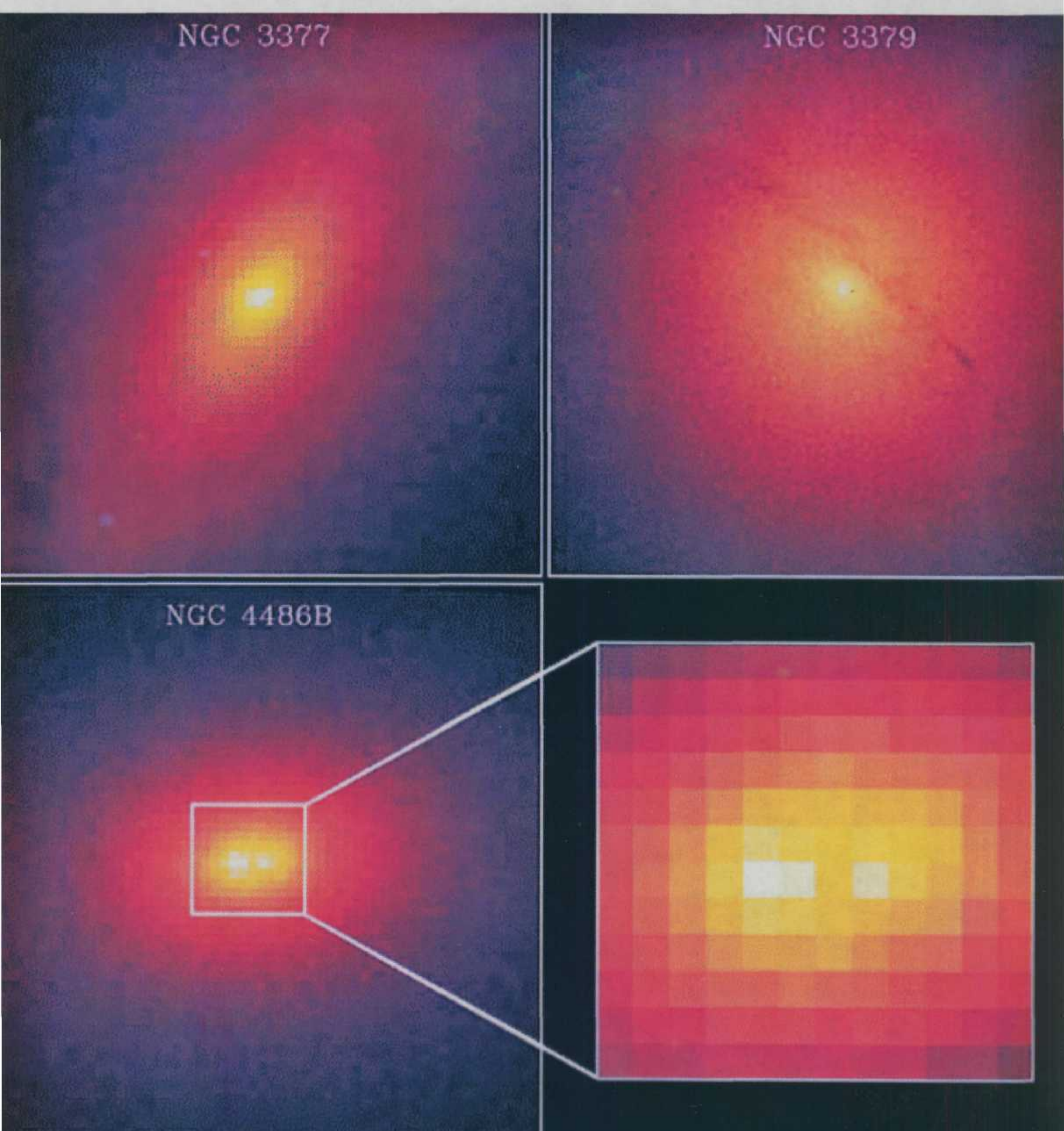

Gas Disk in Nucl
Active Galaxy
Hubble Space Telescope
Wide Field Planetary Camera 2
SPACE
TELESCOPE
SCIENCE
INSTITUTE

Spectrum of Gas Disk in Active Ga



Hubble Space Telescope • Faint Object Spe

SPACE TELESCOPE SCIENCE INSTITUTE



alaxies Possibly Containing Black Holes HST • WFF

C97-01 • ST Scl OPO • January 13, 1997 • K. Gebhardt (U. MI), T. Lauer (NOAO) and NASA

EMBARGOED UNTIL: 2:00 P.M. (EDT)
June 6, 1995

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HUBBLE OBSERVES THE FIRE AND FURY OF A STELLAR BIRTH

NASA's Hubble Space Telescope has provided a detailed look at the fitful, eruptive, and dynamic processes accompanying the final stages of a star's "construction."

Images from the orbiting observatory reveal new details that will require further refinement of star formation theories, according to several independent teams of astronomers that have used Hubble to observe different embryonic stars. The Hubble observations shed new light on one of modern astronomy's central questions: how do tenuous clouds of interstellar gas and dust make stars like our Sun?

"For the first time we are seeing a newborn star close up -- at the scale of our solar system -- and probing the inner workings," said Chris Burrows of the Space Telescope Science Institute,Baltimore, MD and the European Space Agency. "In doing so we will be able to create detailed models of star birth and gain a much better understanding of the formation of our Sun and planets."

The Hubble images provide a dramatically clear look at a collapsing circumstellar disk of dust and gas that builds the star and provides the ingredients for a planetary system, blowtorch-like jets of hot gas funneled from deep within several embryonic systems, and machine-gun like bursts of material fired from the stars at speeds of a half-million miles per hour.

The images offer clues to events that occurred in our solar system when the Sun was born 4.5 billion years ago. Astronomers commonly believe that Earth and the other eight planets condensed out of a circumstellar disk because they lie in the same plane and orbit the Sun in the same direction. According to this theory, when the Sun ignited it blew away the remaining disk, but not before the planets had formed.

"The Hubble images are opening up a whole new field of stellar research for astronomers and clearing up of a decade worth of uncertainty," added Jeff Hester of Arizona State University, Tempe, AZ. "Now we can look so close to a star that many details of star birth become clear immediately."

The key new details revealed by the new Hubble pictures:

* Jets originate from the star and the inner parts of the disk and become confined to a narrow beam within a few billion miles of

their source. It's not known how the jets are focused, or collimated. One theory is that magnetic fields, generated by the star or disk, might constrain the jets.

* Stars shoot out clumps of gas that might provide insights into the nature of the disk collapsing onto the star. The beaded jet structure is a "ticker tape" recording of how clumps of material have, episodically, fallen onto the star. In one case, Hubble allowed astronomers to follow the motion of the blobs and measure their velocity.

* Jets "wiggle" along their multi-trillion-mile long paths, suggesting the gaseous fountains change their position and direction. The wiggles may result from the gravitational influence of one or more unseen protostellar companions.

More generally, Hester emphasizes: "Disks and jets are ubiquitous in the universe. They occur over a vast range of energies and physical scales, in a variety of phenomena." Gaining an understanding of these young circumstellar structures might shed light on similar activity in a wide array of astronomical phenomena: novae, black holes, radio galaxies and quasars.

"The Hubble pictures appear to exclude whole classes of models regarding jet formation and evolution," said Jon Morse of the Space Telescope Science Institute.

A disk appears to be a natural outcome when a slowly rotating cloud of gas collapses under the force of gravity -- whether the gas is collapsing to form a star, or is falling onto a massive black hole. Material falling onto the star creates a jet when some of it is heated and blasted along a path that follows the star's rotation axis, like an axle through a wheel.

Jets may assist star formation by carrying away excess angular momentum that otherwise would prevent material from reaching the star. Jets also provide astronomers with a unique glimpse of the inner workings of the star and disk. "Not even the Hubble Telescope can watch as material makes it final plunge onto the surface of the forming star, but the new observations are still telling us much about that process," said Hester.

Burrows, Hester, Morse and their co-investigators independently observed several star birth sites in our galactic neighborhood. "All of these objects tell much the same story," Hester emphasized. "We are clearly seeing a process that is a crucial part of star formation, and not just the peculiarities of a few oddball objects."

The researchers all agree that the Hubble pictures generally confirm models of star formation but will send theorists back to the drawing board to explain the details. The researchers emphasize that future models of star formation will have to take into account why jets are ejected from such a well-defined region in the disk, why jets are collimated a few billion miles out from the star, and why gas in the jets is ejected quasi-periodically.

Changes are occurring so rapidly in the jets that Hubble will be able to follow their evolution of these objects over the next decade.

* * * * * *

The Space Telescope Science Institute is operated by the Association of Universities for Research in Astronomy, Inc. (AURA) for NASA, under contract with the Goddard Space Flight Center, Greenbelt, MD. The Hubble Space Telescope is a project of international cooperation between NASA and the European Space Agency (ESA).

Image files in GIF and JPEG format may be accessed on Internet via anonymous ftp from oposite.stsci.edu in /pubinfo:

		GIF	JPEG
PRC95-24a	HH30/HH34/HH47	gif/JetDisk3	jpeg/JetDisk3
PRC95-24b	HH30 Jet Motion	gif/HH30	jpeg/HH30
PRC95-24c	HH1/HH2 Details	gif/HH1-2	jpeg/HH1-2
PRC95-24d	HH47 Jet Detail	gif/HH47	jpeg/HH47

The same images are available via World Wide Web from URL http://www.stsci.edu/Latest.html, or via links in http://www.stsci.edu/public.html.

SCIENCE BACKGROUND

STELLAR DISKS AND JETS

Stellar jets are analogous to giant lawn sprinklers. Whether a sprinkler whirls, pulses or oscillates, it offers insights into how its tiny mechanism works. Likewise stellar jets, billions or trillions of miles long offer some clues to what's happening close into the star at scales of only millions of miles, which are below even Hubble's ability to resolve detail. Hubble's new findings address a number of outstanding questions:

Where Are Jets Made?

Hubble shows that a jet comes from close into a star rather than the surrounding disk of material. Material either at or near the star is heated and blasted into space, where it travels for billions of miles before colliding with interstellar material.

Why Are Jets So Narrow?

The Hubble pictures increase the mystery as to how jets are confined into a thin beam. The pictures tend to rule out the earlier notion that a disk was needed to form a nozzle for collimating the jets, much like a garden hose nozzle squeezes water to a narrow stream. One theoretical possibility is that magnetic fields in the disk might focus the gas into narrow beams, but there is as yet no direct observational evidence that magnetic fields are important.

What Causes a Jet's Beaded Structure?

Hubble is solving the puzzle of a unique beaded structure in the jets, first detected from the ground but never fully understood.

"Before the Hubble observations the emission knots were a mystery," said Jeff Hester. "Many astronomers thought that the knots were the result of interactions of the jet with the gas that the jet is passing through, while others thought that the knots were due to 'sputtering' of the central engine. We now know that the knots are the result of sputtering." Hester bases this conclusion on Hubble images which show the beads are real clumps of gas plowing through space like a string of motor boats. Competing theories, now disproved by Hubble, suggested a hydrodynamic effect such as shock-diamond patterns seen in the exhaust of a jet fighter.

What Do Jets Tell Us about Star Birth?

"The jet's clumpy structure is like a stockbroker's ticker tape; they represent a recorded history of events that occurred close to the star," said Jon Morse. "The spacing of the clumps in the jet reveals that variations are occurring on several time scales close to the star where the jet originates. Like a "put-put" motor, variations every 20 to 30 years create the strings of blobs we see," Morse concluded. "However, every few hundred years or so, a large amplitude variation generates a 'whopper' of a knot, which evolves into one of the major bow-shaped shock waves." Other Hubble views by Chris Burrows reveal new blobs may be ejected every few months. "If the circumstellar disk drives the jet then the clumpiness of the jet provides an indirect measure of irregularities in the disk."

Why Are Jets "Kinky"?

The Hubble pictures also show clear evidence that jets have unusual kinks along their path of motion. This might be evidence for a stellar companion or planetary system that pulls on the central star, causing it to wobble, which in turn causes the jet to change directions, like shaking a garden hose. The jet blast clears out material around the star, and perhaps determines how much gas finally collapses onto the star.

Star Formation

A star forms through the gravitational collapse of a vast cloud of interstellar hydrogen. According to theory, and confirmed by previous Hubble pictures, a dusty disk forms around the newborn star. As material falls onto the star, some of it can be heated and ejected along the star's spin axis as opposing jets. These jets of hot gas blaze for a relatively short period of the star's life, less than 100,000 years. However, that brief activity can predestine the star's evolution, since the final mass of a star determines its longevity, temperature, and ultimate fate. The jet might carry away a significant fraction of the material falling in toward the star, and, like a hose's water stream plowing into sand, sweeps out a cavity around the star that prevents additional gas from falling onto the circumstellar disk.

Historical Background

In the early 1950's, American astronomer George Herbig and Mexican astronomer Guillermo Haro independently catalogued several enigmatic "clots" of nebulosity near stars near the Orion nebula that have since been called Herbig-Haro objects. It is only in the last 20 years, however, that the true nature of these objects, and their role in the star formation process, has been revealed. Careful study showed that many of the Herbig-Haro objects represent portions of high-speed jets streaming away from nascent stars. Now there are nearly 300 Herbig-Haro objects identified by astronomers around the world, and the list is growing as new technologies and techniques are developed to probe the dusty depths of nearby stellar nurseries.

EMBARGOED UNTIL: 2:00 P.M. (EDT)
JUNE 6, 1995

PHOTO RELEASE NO.: STSCI-PRC95-24a

HUBBLE VIEWS OF THREE STELLAR JETS

These NASA Hubble Space Telescope views of gaseous jets from three newly forming stars show a new level of detail in the star formation process, and are helping to solve decade-old questions about the secrets of star birth. Jets are a common "exhaust product" of the dynamics of star formation. They are blasted away from a disk of gas and dust falling onto an embryonic star.

[upper left] - This view of a protostellar object called HH-30 reveals an edge-on disk of dust encircling a newly forming star. Light from the forming star illuminates the top and bottom surfaces of the disk, making them visible, while the star itself is hidden behind the densest parts of the disk. The reddish jet emanates from the inner region of the disk, and possibly directly from the star itself. Hubble's detailed view shows, for the first time, that the jet expands for several billion miles from the star, but then stays confined to a narrow beam. The protostar is 450 light-years away in the constellation Taurus.

Credit: C. Burrows (STScI & ESA), the WFPC 2 Investigation
Definition Team, and NASA

[upper right] - This view of a different and more distant jet in object HH-34 shows a remarkable beaded structure. Once thought to be a hydrodynamic effect (similar to shock diamonds in a jet aircraft exhaust), this structure is actually produced by a machine-gun-like blast of "bullets" of dense gas ejected from the star at speeds of one-half million miles per hour. This structure suggests the star goes through episodic "fits" of construction where chunks of material fall onto the star from a surrounding disk. The protostar is 1,500 light-years away and in the vicinity of the Orion Nebula, a nearby star birth region.

Credit: J. Hester (Arizona State University), the WFPC 2 Investigation
Definition Team, and NASA

[bottom] - This view of a three trillion mile-long jet called HH-47 reveals a very complicated jet pattern that indicates the star (hidden inside a dust cloud near the left edge of the image) might be wobbling, possibly caused by the gravitational pull of a companion star. Hubble's detailed view shows that the jet has burrowed a cavity through the dense gas cloud and now travels at high speed into interstellar space. Shock waves form when the jet collides with interstellar gas, causing the jet to glow. The white filaments on the left reflect light from the obscured newborn star. The HH-47 system is 1,500 light-years away, and lies at the edge of the Gum Nebula, possibly an ancient supernova remnant which can be seen from Earth's southern hemisphere.

Credit: J. Morse/STScI, and NASA

The scale in the bottom left corner of each picture represents 93 billion miles, or 1,000 times the distance between Earth and the Sun. All images were taken with the Wide Field Planetary Camera 2 in visible light. The HH designation stands for "Herbig-Haro" object -- the name for bright patches of nebulosity which appear to be moving away from associated protostars.

EMBARGOED UNTIL: 2:00 P.M. (EDT) JUNE 6, 1995

PHOTO RELEASE NO.: STSCI-PRC95-24b

MOTION OF JETS FROM AN EMBRYONIC STAR (HH-30)

This NASA Hubble Space Telescope image reveals unprecedented detail in a newly forming star called HH-30. Exposures taken a year apart show the motion of high speed blobs of gas (arrows) that are being ejected from the star at a half-million miles per hour.

The jets emanate from the center of a dark disk of dust which encircles the star and hides it from view. Presumably the disk feeds material onto the star, and some of it is superheated and squirts out along the star's spin axis. The presence of the blobs suggests that the star formation process is fitful and episodic, as chunks of material fall onto the newborn star.

For the first time, Hubble Space Telescope shows the accretion disk which is about the size of our solar system, around a forming star. The top and bottom surfaces of the disk can be seen directly in this view, which visually confirms the conventional accretion disk theory for star formation. When the star becomes hot enough it will stop accreting material and blow away much of the disk -- but perhaps not before planets have formed around the star. The generally accepted theory for the creation of our solar system is that it formed from a disk, and that the orbits of the planet are the "skeletal" remnant of the disk. It also explains why the planets all orbit the Sun in the same direction and roughly the same plane. The disk can be seen to "flare" away from the star. (It is thicker at larger distances from the star.) This behavior can be understood because it takes material farther out in the disk longer to settle to the disk midplane. The flaring has been conjectured in order to explain details of the spectra of such objects, but never directly observed before on these scales.

The picture was taken with the Wide Field Planetary Camera 2. HH-30 lies 450 light-years away in the constellation Taurus.

Credit: C. Burrows (STScI & ESA), the WFPC 2 Investigation Definition Team, and NASA
Co-investigators: K. Stapelfeldt (JPL), A Watson (Lowell Observatory)

EMBARGOED UNTIL: 2:00 P.M. (EDT)
JUNE 6, 1995

PHOTO RELEASE NO.: STSCI-PRC95-24c

PAIR OF JETS FROM A YOUNG STAR (HH1/HH2)

This NASA Hubble Space Telescope image reveals new secrets of star birth as revealed in a pair of eerie spectacular jet of gas the star has ejected by a young star.

[top] - Tip to tip, this jet spans slightly more than a light-year. The fountainhead of this structure -- the young star -- lies midway between the jet, and is hidden from view behind a dark cloud of dust. The nearly symmetrical blobs of gas at either end are where the jet has slammed into interstellar gas.

[bottom left] - A close-up of a region near the star reveals a string of glowing clumps of gas, ejected by the star in machine-gun like burst fashion. This provides new clues to the dynamics of the star formation process. The jets are ejected from a whirlpool of gas and dust orbiting the young star.

[bottom right] - This arrowhead structure is a classic bowshock pattern produced when high-speed material encounters a slower-speed medium. Young stellar jets were discovered 20 years ago, in part due to visible-light observations of bright patches of nebulosity (called Herbig-Haro objects), which appear to be moving away from associated protostars.

The picture was taken with the Wide Field Planetary Camera 2. HH-1/ HH-2 lies 1,500 light-years away in the constellation Orion.

Credit: J. Hester (Arizona State University), the WFPC 2 Investigation Definition Team, and NASA

EMBARGOED UNTIL: 2:00 P.M. (EDT)
JUNE 6, 1995

PHOTO RELEASE NO.: STSCI-PRC95-24d

WIGGLING JET FROM A WOBBLING STAR (HH-47)

This NASA Hubble Space Telescope image reveals new secrets of star birth as recorded in a spectacular jet of gas the star has ejected.

[center] - Resembling the vertebrae of an imaginary space alien, this one-half light-year long jet of gas has burst out of a dark cloud of gas and dust which hides the newly forming star located in the lower left corner of the image.

[upper left] - An enlargement of a portion of the jet near the star shows the complicated interactions that take place when the ejected gas collides with the interstellar medium. The apparent changes in direction might be produced by wobbling of the star, as it feels the gravitational tug of an unseen companion star or instability mechanisms.

[lower right] - A massive clump of jet material collides with upstream gas and creates a bow-shaped shock wave, like a boat speeding across a lake. Through this process the jet sweeps out a cavity around the star and may thereby restrict how much material is available to fall onto the star as part of the gravitational accretion process.

The images used to make this picture were taken with the Wide Field Planetary Camera 2 on March 26 and 29, 1994. HH-47 lies about 1,500 light-years away in the constellation Vela. The star is forming in a dense gas cloud at the edge of the Gum Nebula.

Credit: J. Morse (STScI), and NASA
Co-investigators: B. Reipurth (European Southern Observ.), S. Heathcote (Cerro Tololo Inter-American Observ.), P. Hartigan (Rice Univ.), J. Bally (Univ. of Colorado), R. Schwartz (Univ. of Missouri), J. Stone (Univ. of Maryland).

The insets show portions of the jet that were computer enhanced by A. Boden and D. Redding (JPL) and J. Mo and R. Hanisch (STScI).