Lecture 20b

Active Galactic Nuclei

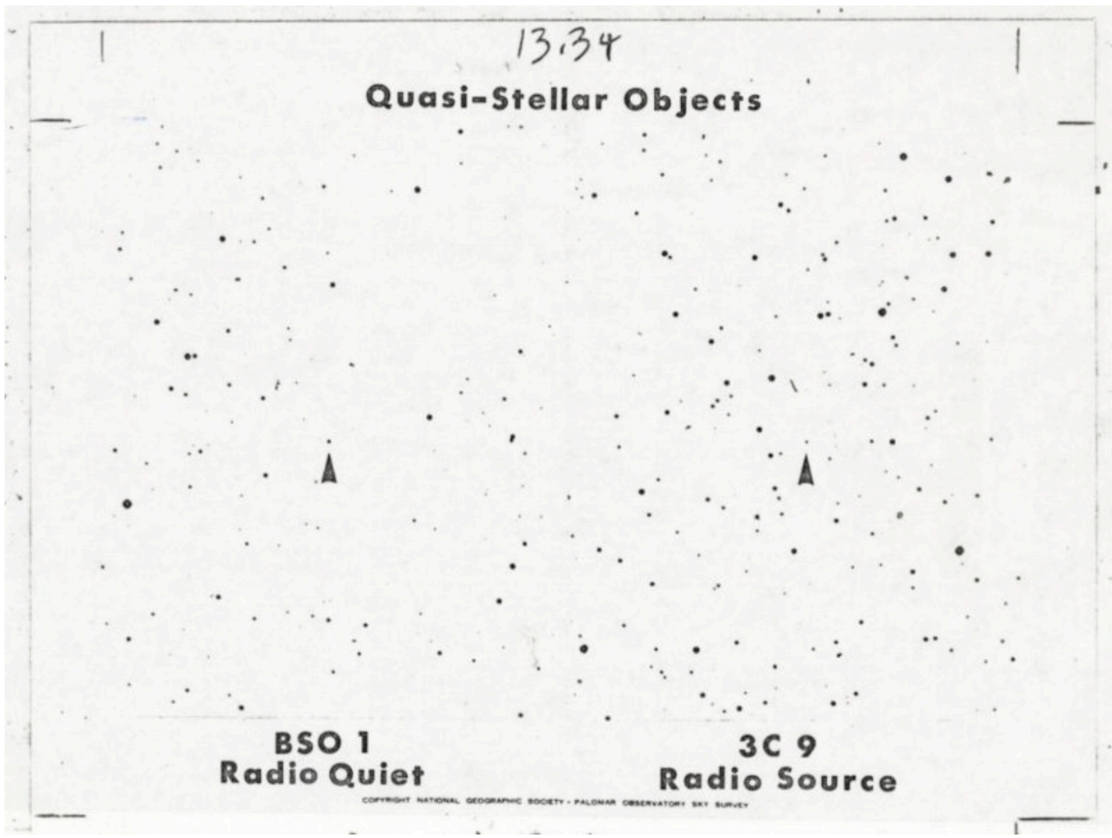
(extra material not covered in course)

Outline of Lecture 20b

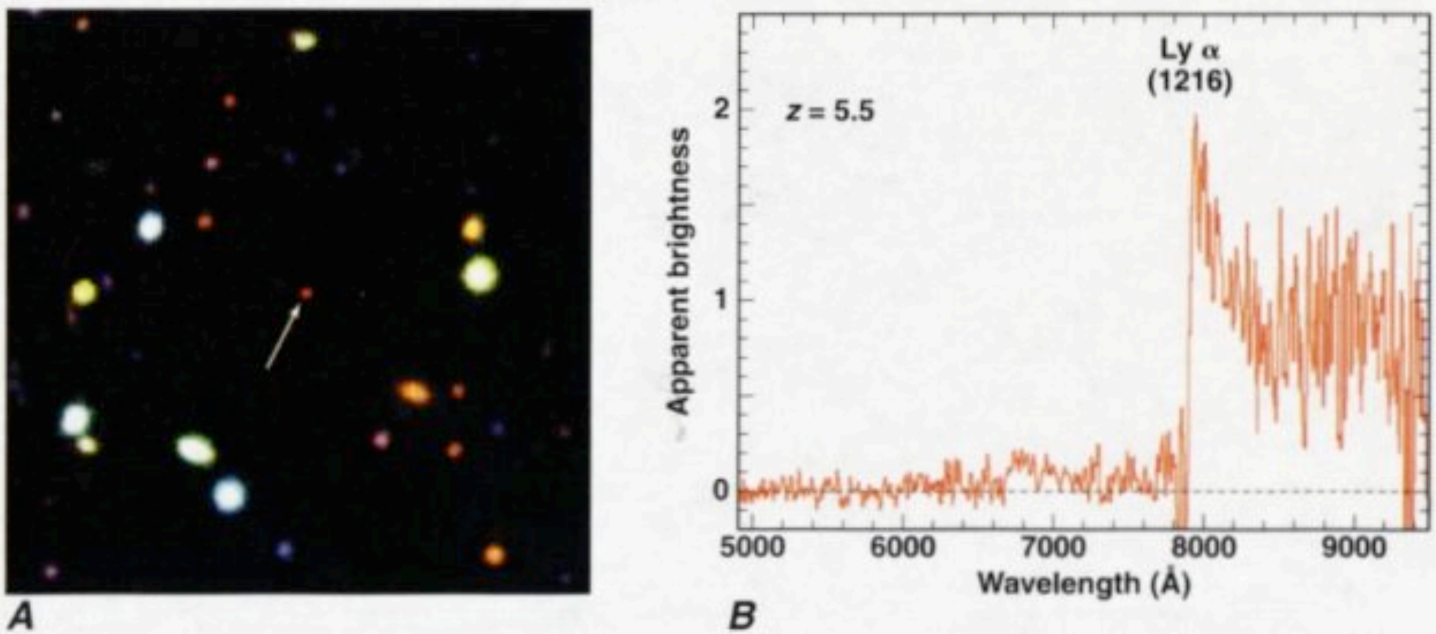
- Quasi-Stellar Objects (QSOs) and quasars (QSOs that emit copious radio radiation) are indistinguishable from pointlike stars on ordinary astronomical photographs. They are now understood to be the *nuclei* at the centers of galaxies.
- The enormous energy output of QSOs and quasars (in the form of radio, optical, and X-ray emission, as well as the ejection of powerful jets) is believed to be powered by the *accretion of matter* through a *disk* onto a *supermassive black hole*.
- The nucleus of our own Galaxy, the Milky Way system, appears to harbor such a supermassive black hole of about 2.6 million solar masses.

This Lecture is not given in Fall 2006; material is being supplied for interested students, but it will not be covered in quizzes.

Quasars and QSOs Look Like Stars in Ordinary Photographs

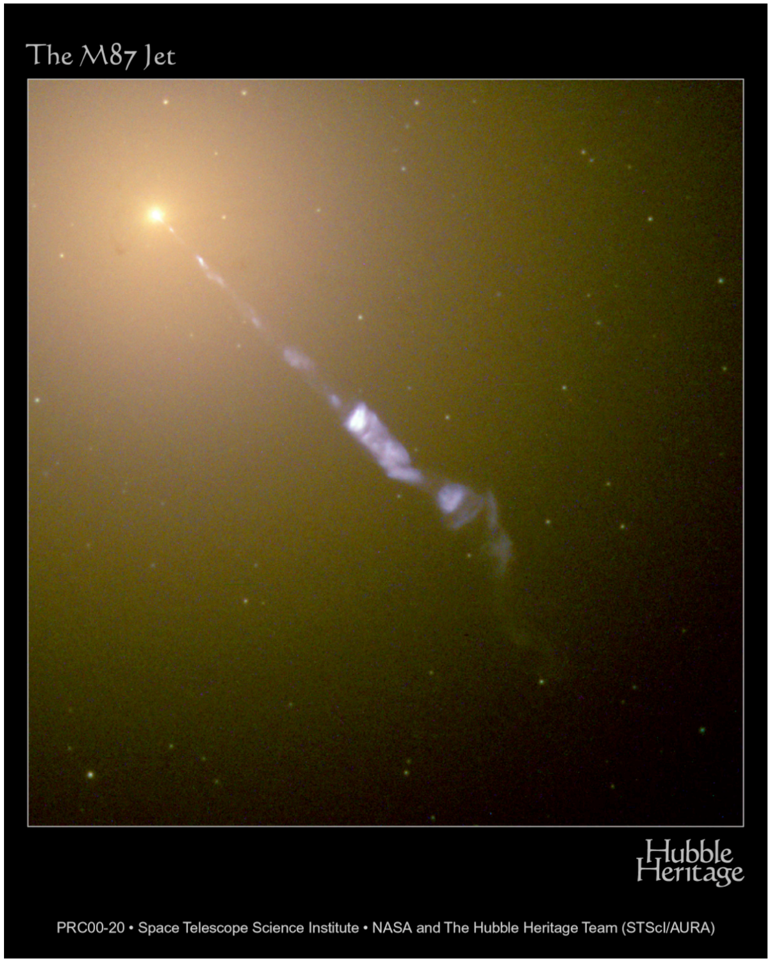


QSOs Usually Have Large Redshifts

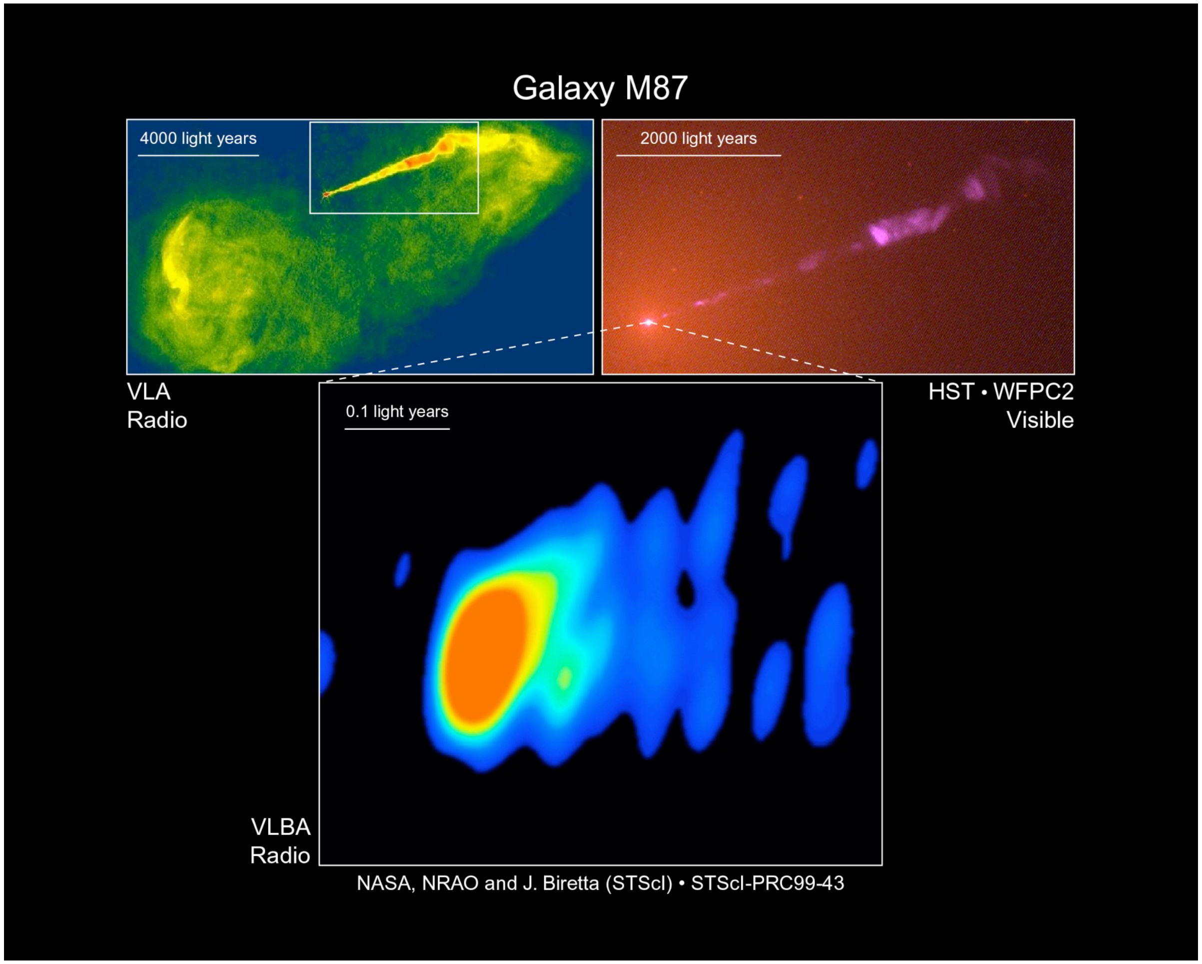


Probably the nuclei of active galaxies at very great distances from Earth

Optical Jet Emanating from Nucleus of M87, an Elliptical Galaxy in the Virgo Cluster

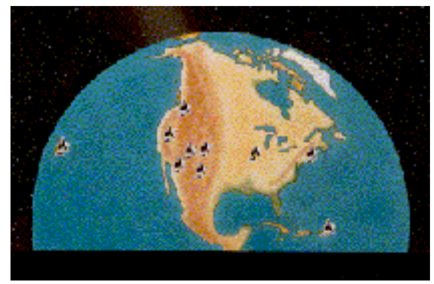


M87's Jet Has Associated Nonthermal Radio Emission



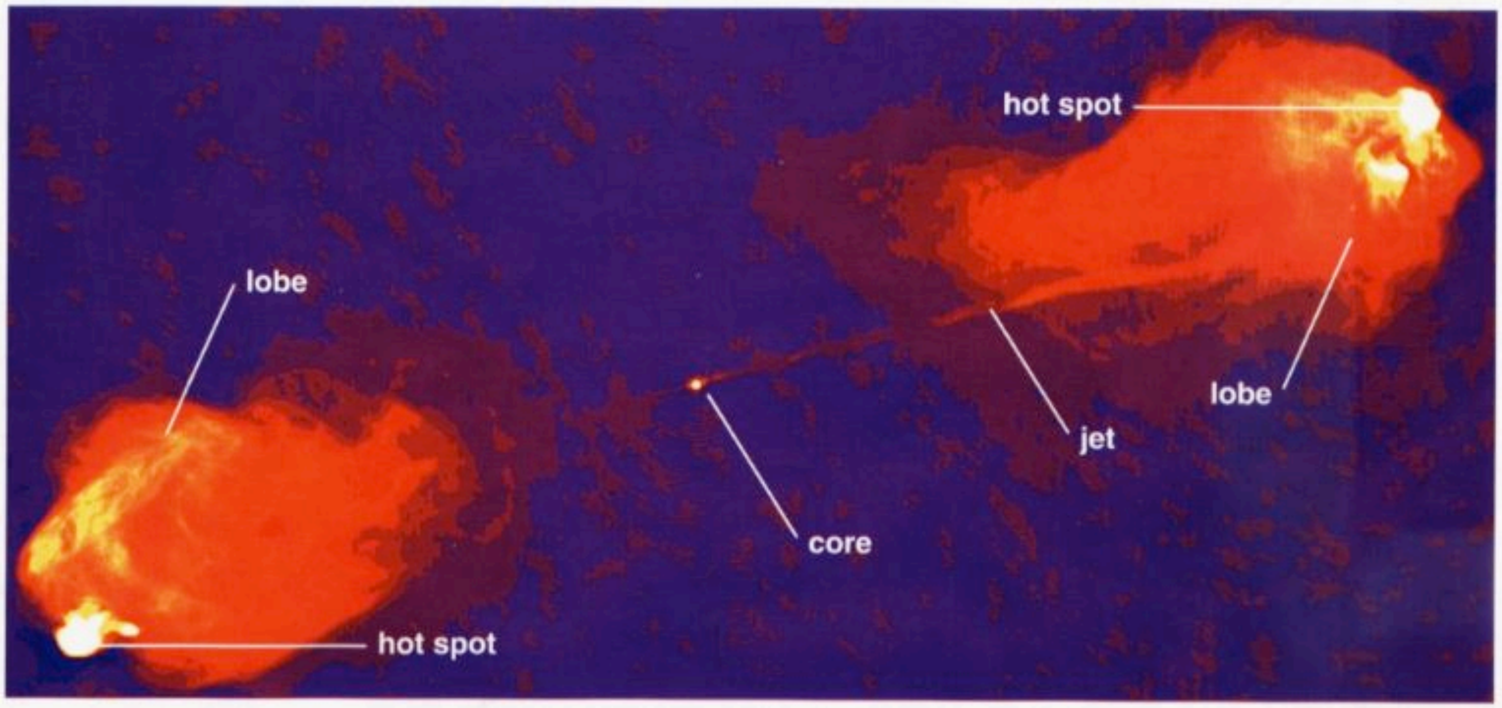
Radio Maps Are Made by Interferometric Arrays Like VLA and VLBA

VLA

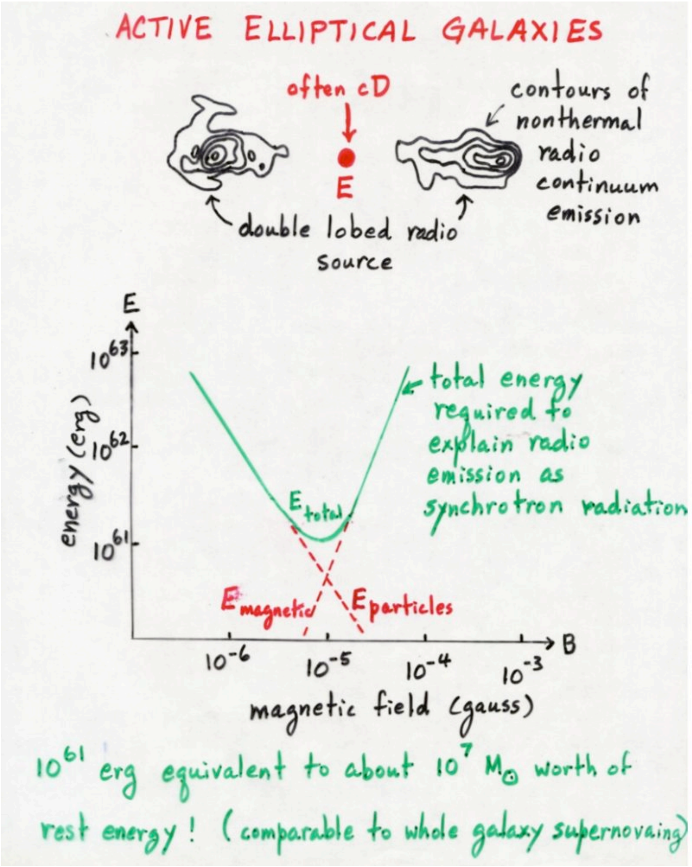


VLBA

Large Radio Lobes Are Powered by Jets from Galactic Nucleus



Enormous Energy Requirements of Emission from Radio Galaxies



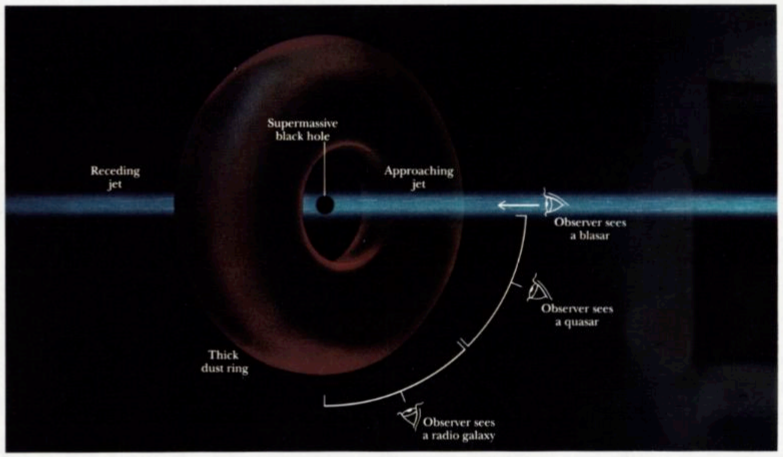
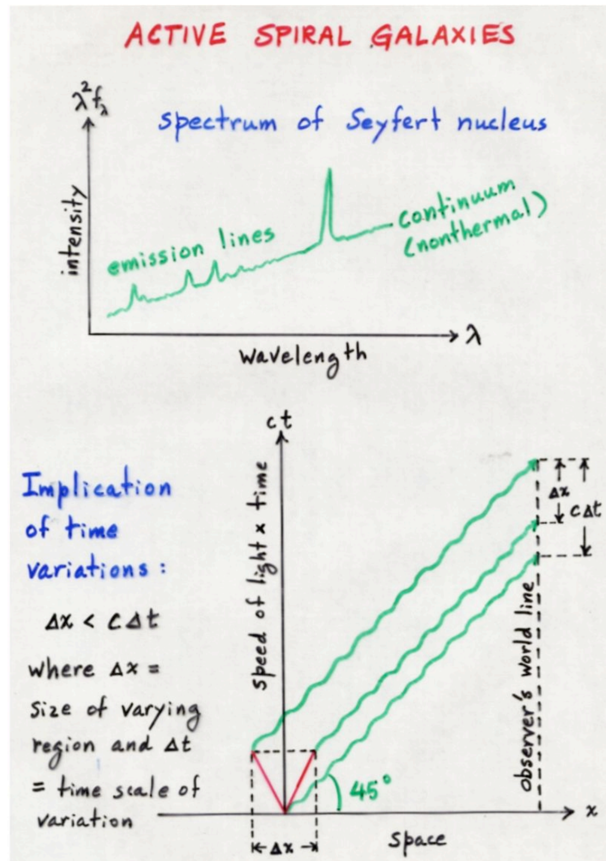


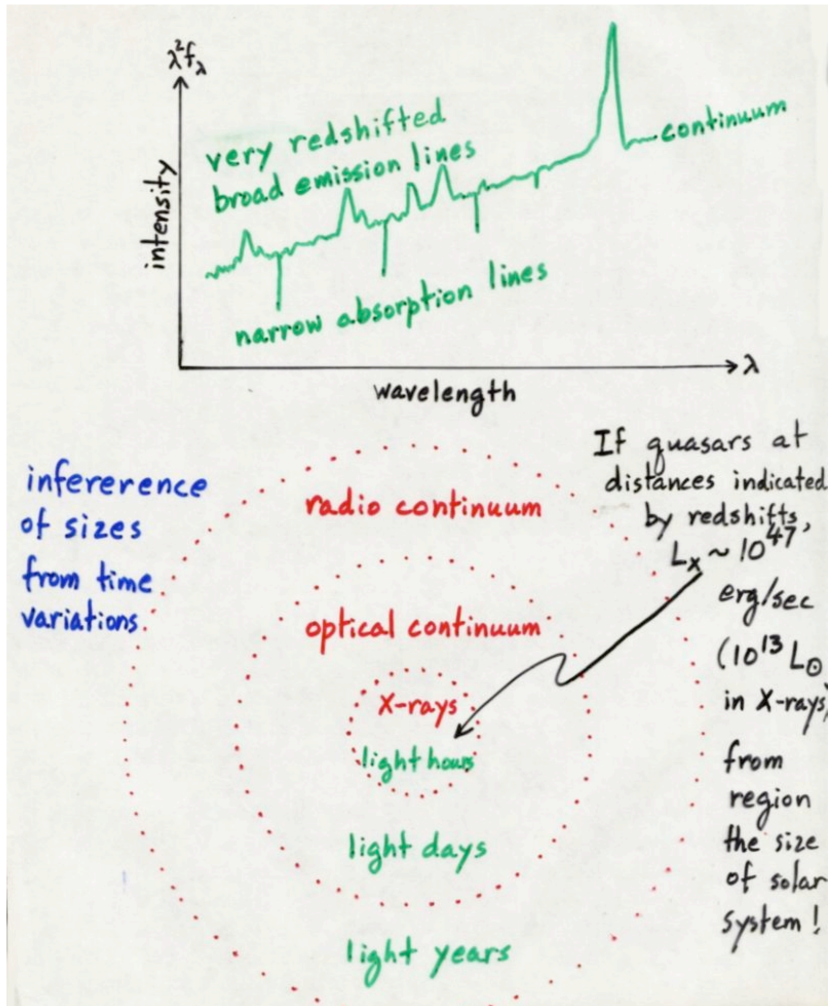
Figure 27-33
Kaufmann: UNIVERSE, Third Edition

T-73

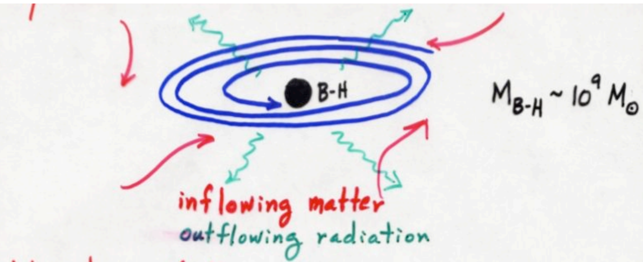
Seyferts Are Spiral Galaxies with Very Bright, Time Variable Nuclei



Schematic Model for Quasars

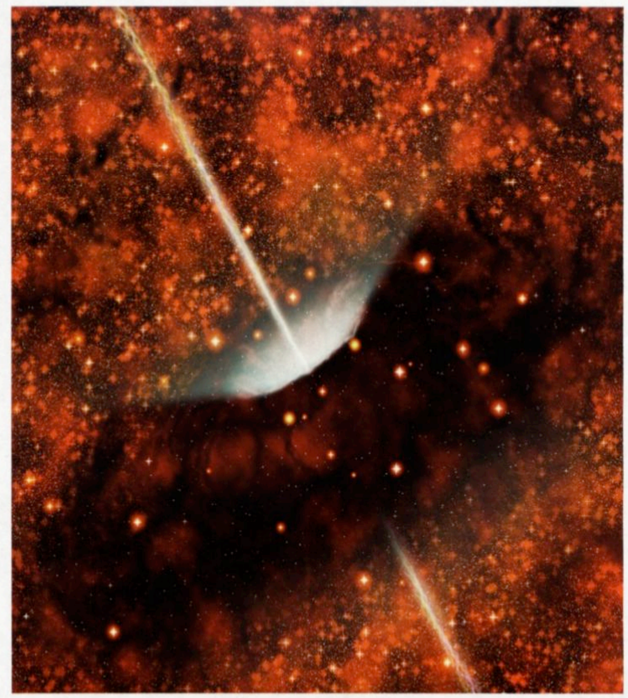


Supermassive BH Model for AGNs

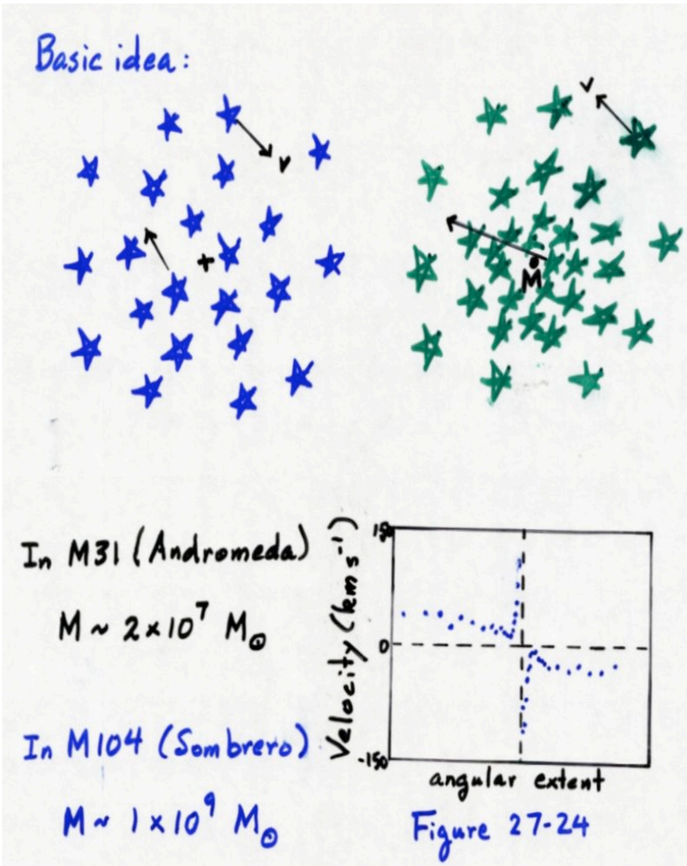


Advantages of this model:

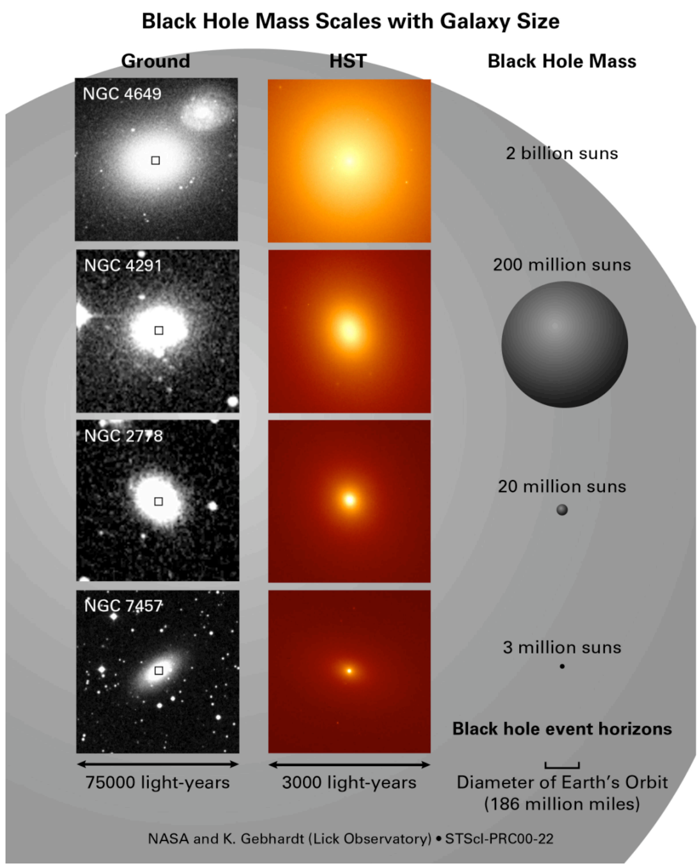
- BH which swallows $10\ M_\odot/yr$, producing energy by mass deficit of about 10%, would release total luminosity of about 10^{47} erg/sec.
- To have an inward gravitational pull which overwhelms radiation pressure on matter resulting from luminosity of 10^{47} erg/sec, the mass of the B-H has to equal or exceed $10^9 M_\odot$.
- The Schwarzschild "radius" $R_{Sch} = 2GM/c^2$ associated with a $10^9 M_\odot$ B-H is 3×10^{14} cm or 10^4 lt sec (3 lt hr). Thus, the size of the event horizon is compatible with fastest time variations seen in active galactic nuclei.
- $10\ M_\odot/yr$ for 10^8 yr $= 10^9 M_\odot$.



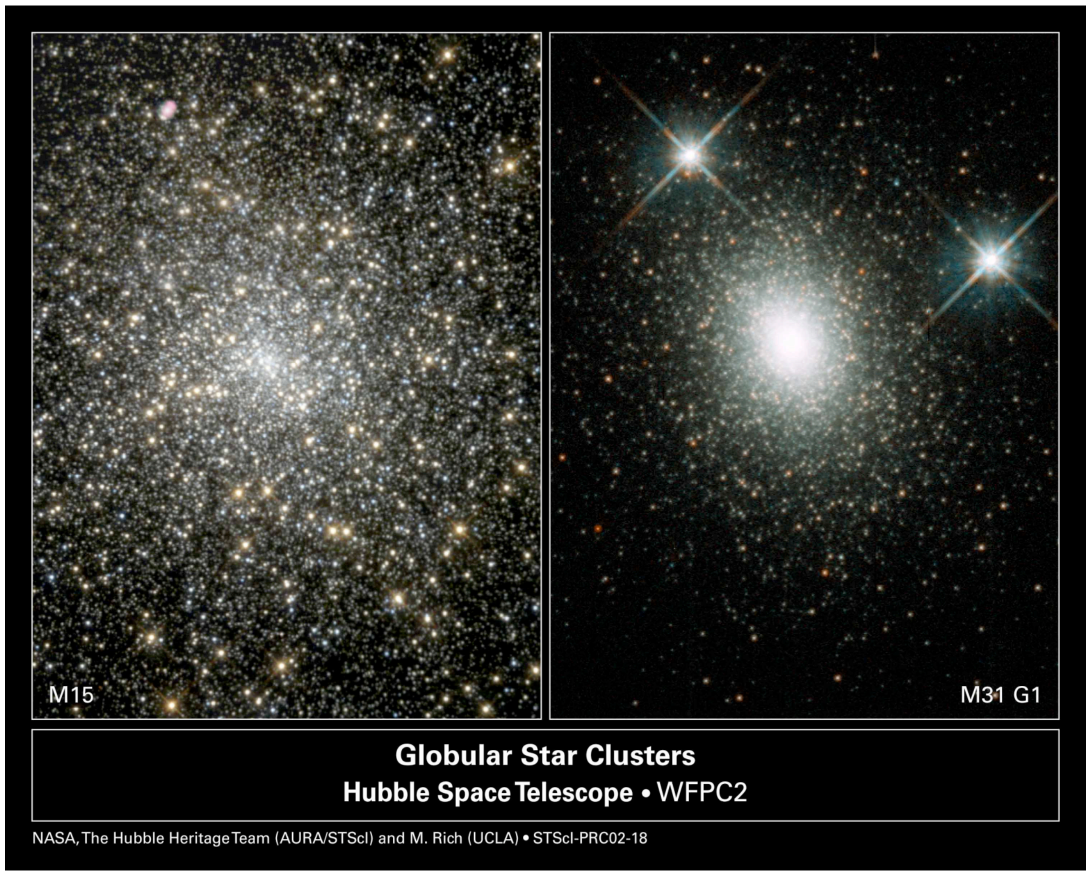
Observational Attempts to Detect Supermassive BHs in Galactic Nuclei



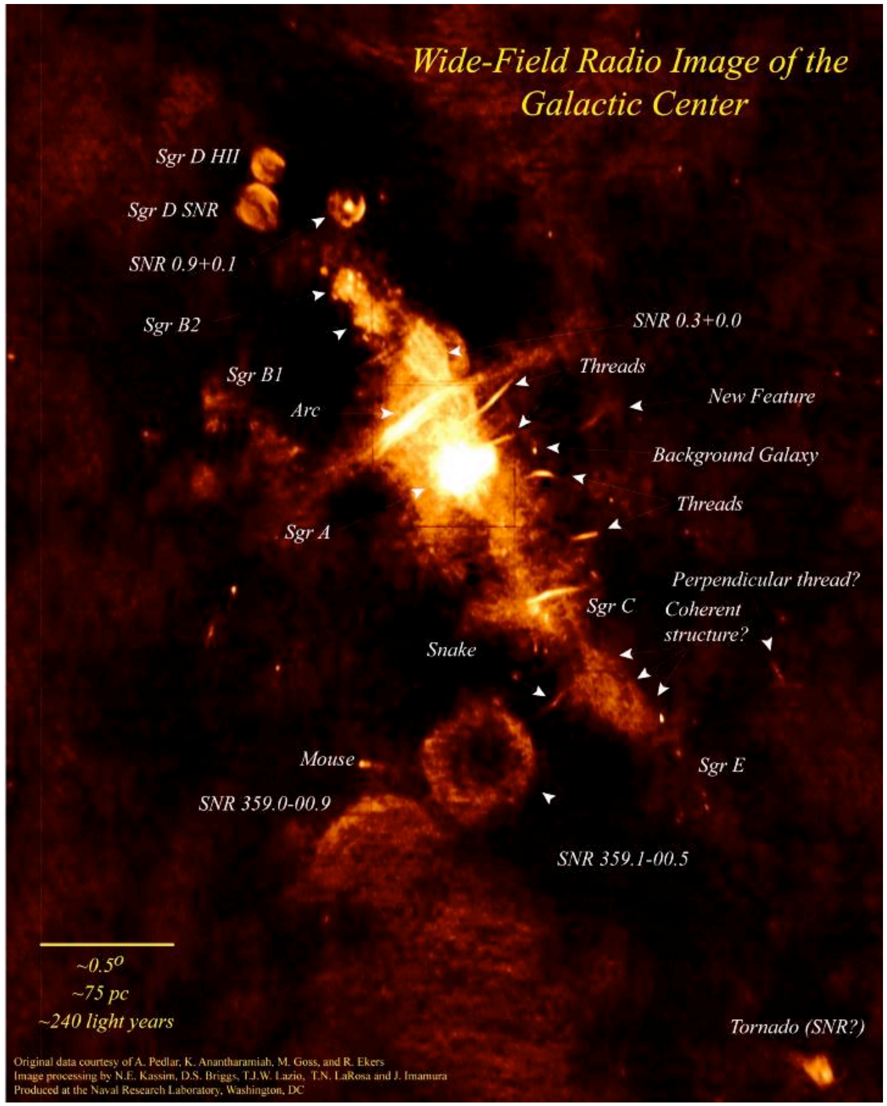
Masses of BHs at Galactic Nuclei Scale with Host Galaxies



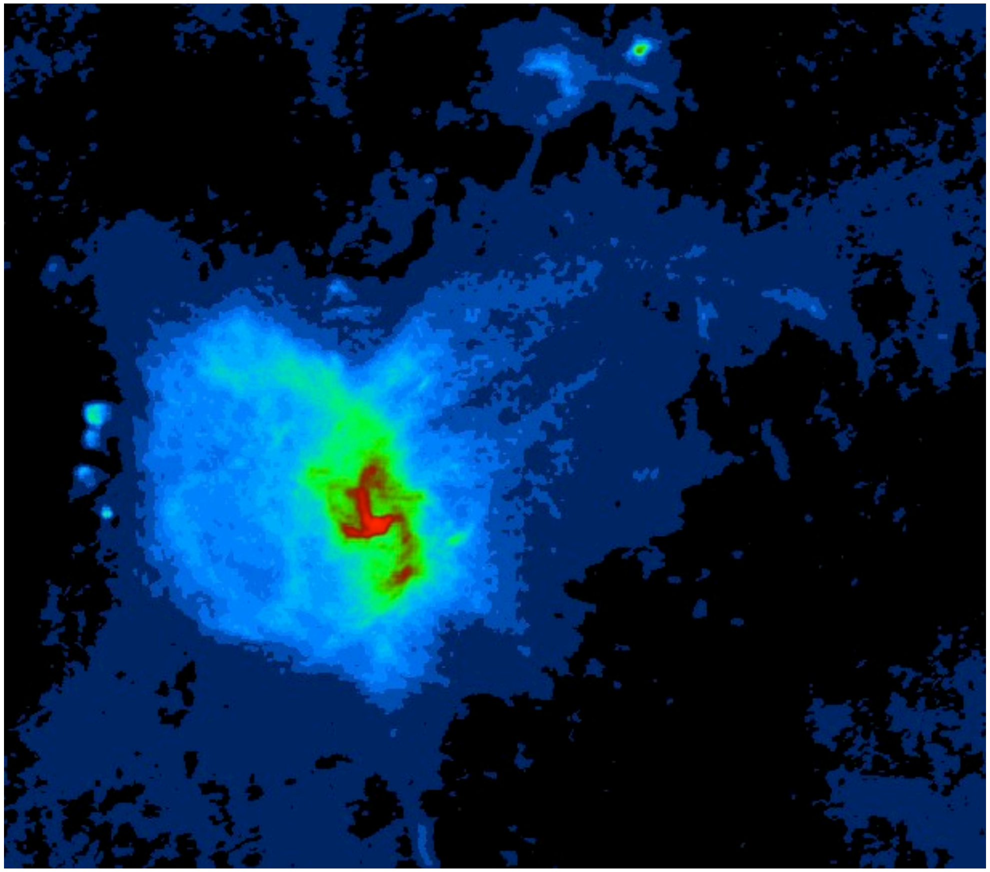
By Same Technique these Globular Clusters Are Found to Contain BHs of 4,000 and 20,000 Solar Masses



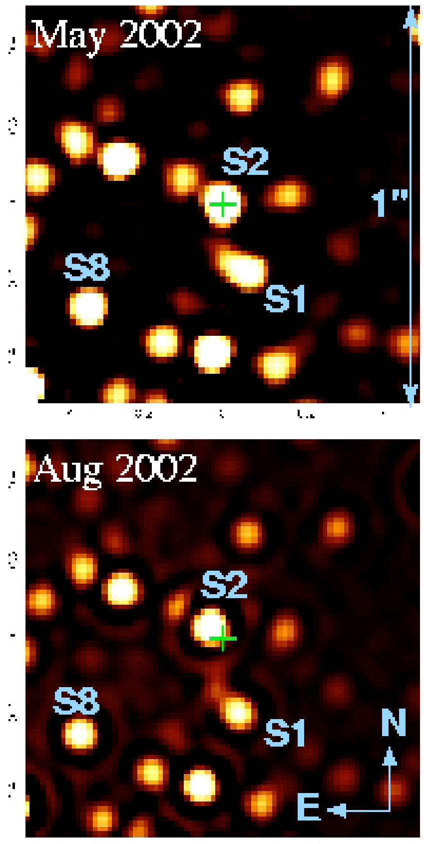
Central Region of Our Galaxy

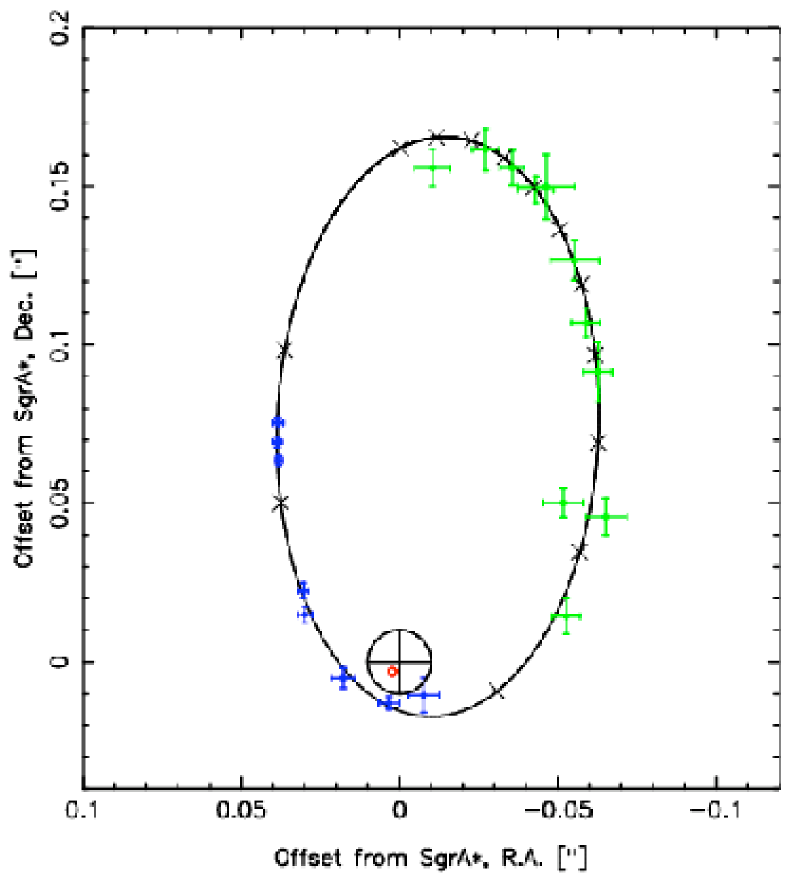


Center of Our Galaxy Contains Magnetic Threads and Mini-Spiral Surrounding Radio Source Sgr A*



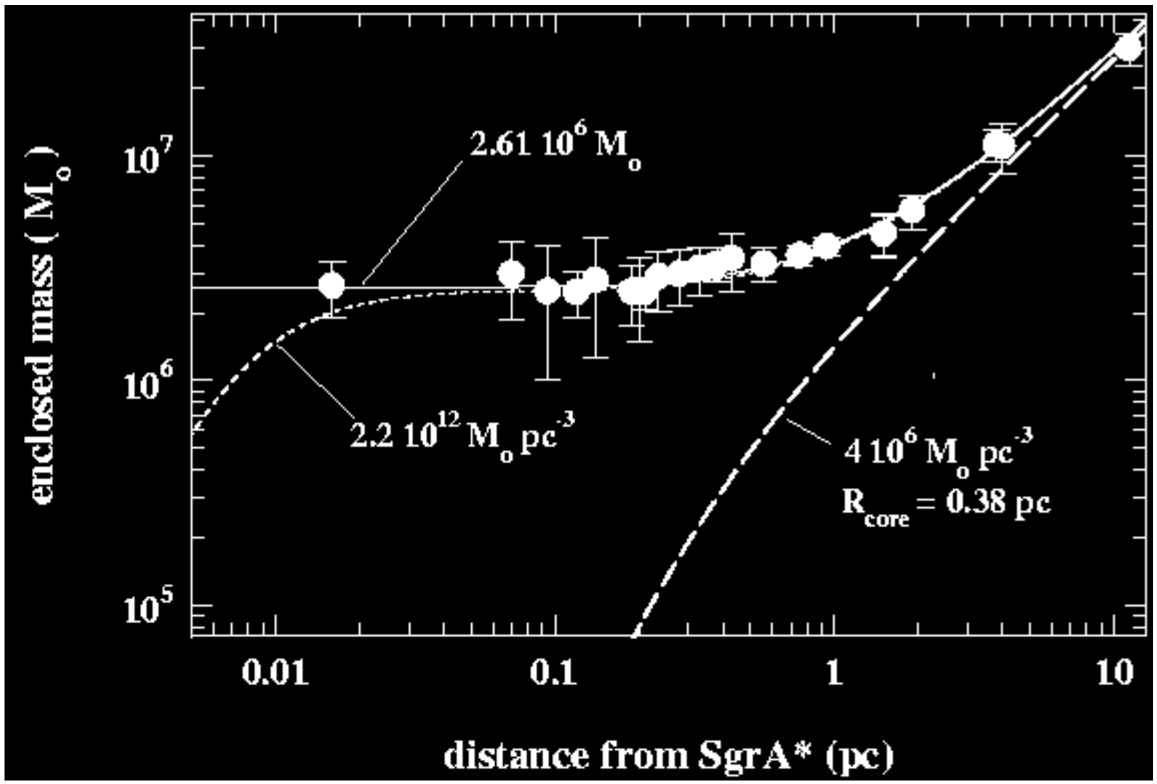
Orbit of Star S2 About Sgr A*





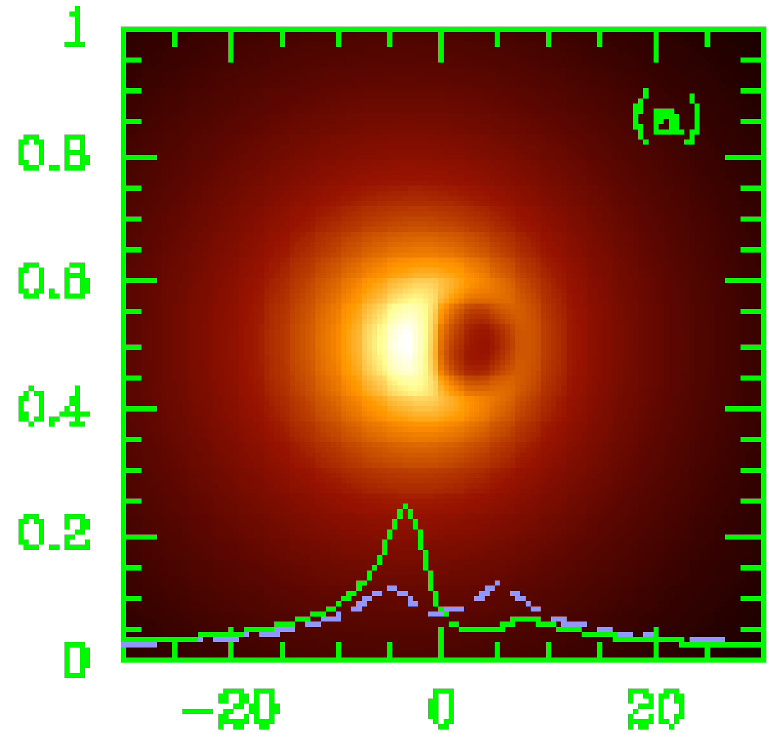
UCLA

Motions Suggest Mass of 2.6 Million Solar Masses for BH (Sgr A*)



Sgr A* Is an Inactive Galactic Nucleus Because It Is Not Accreting Actively

- For incompletely understood reasons, mass accretion rate onto Sgr A* is currently inordinately low.
- When M31 and Milky Way merge in future, however, their central BHs will spiral into each other, accompanied by lots of surrounding interstellar matter.
- At that time, very powerful jets may shoot at relativistic speeds through the merged galaxy. Maybe it'll be possible to sail this high-speed wind to unexplored ports!
- In the interim because Sgr A* is so quiet, it constitutes a relatively clean environment to study the curious gravitational lensing that is predicted by general relativity to occur around a rotating, supermassive, black hole.



Imagine imaging a bright disk orbiting a maximally rotating black hole. The example shown above assumes a flat disk with intrinsic r^{-2} emissivity viewed at an inclination angle of 45°. A shadow of the hole is formed by light rays passing too close to the event horizon and falling into it. Other brightening and darkening effects are caused by a combination of Doppler, frame-dragging, and gravitational redshift effects. (Heino Falcke@mpifr@bonn.mpq.de)