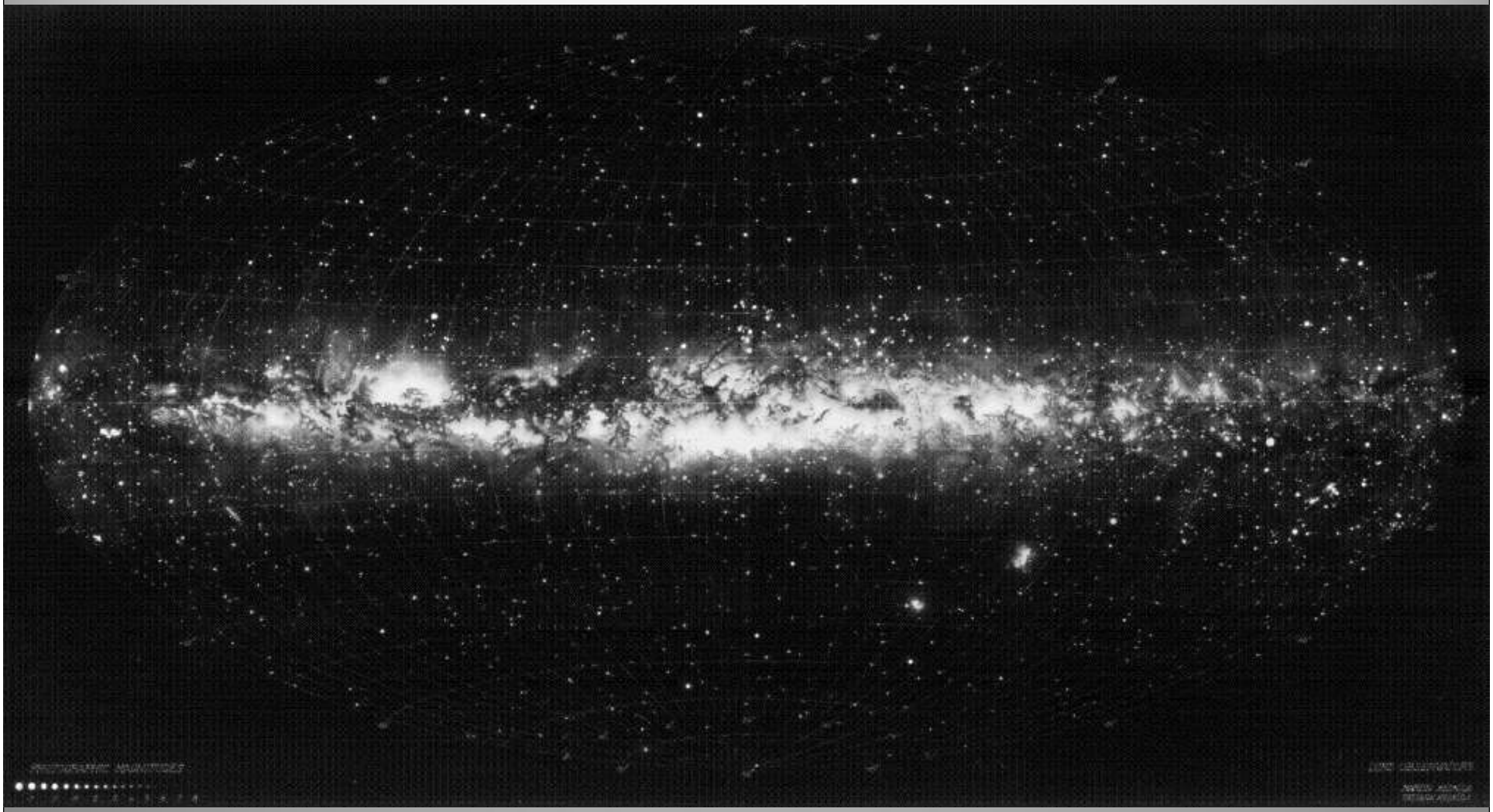
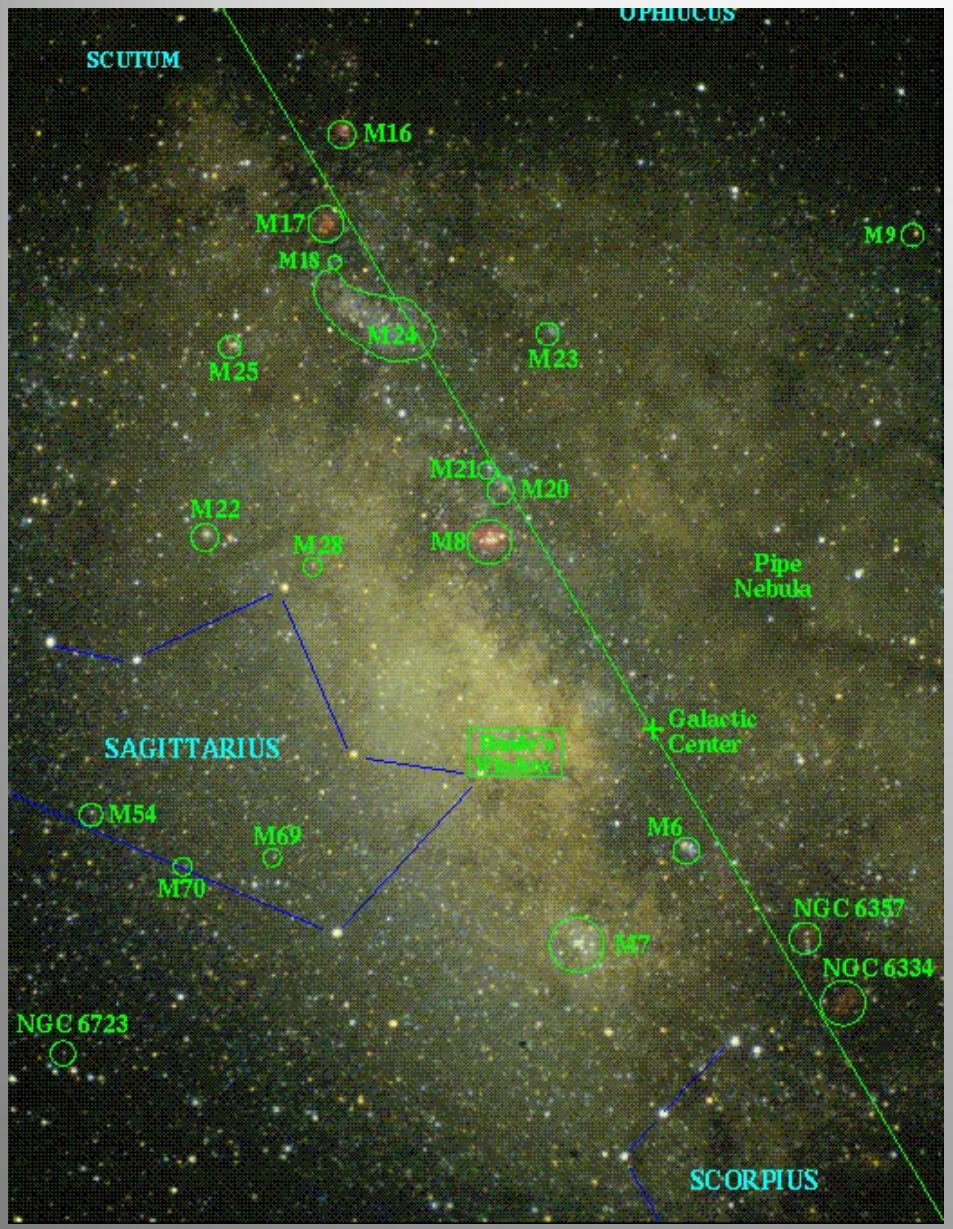
THE GALACTIC CENTER

aka The Center of the Milky Way


We are here



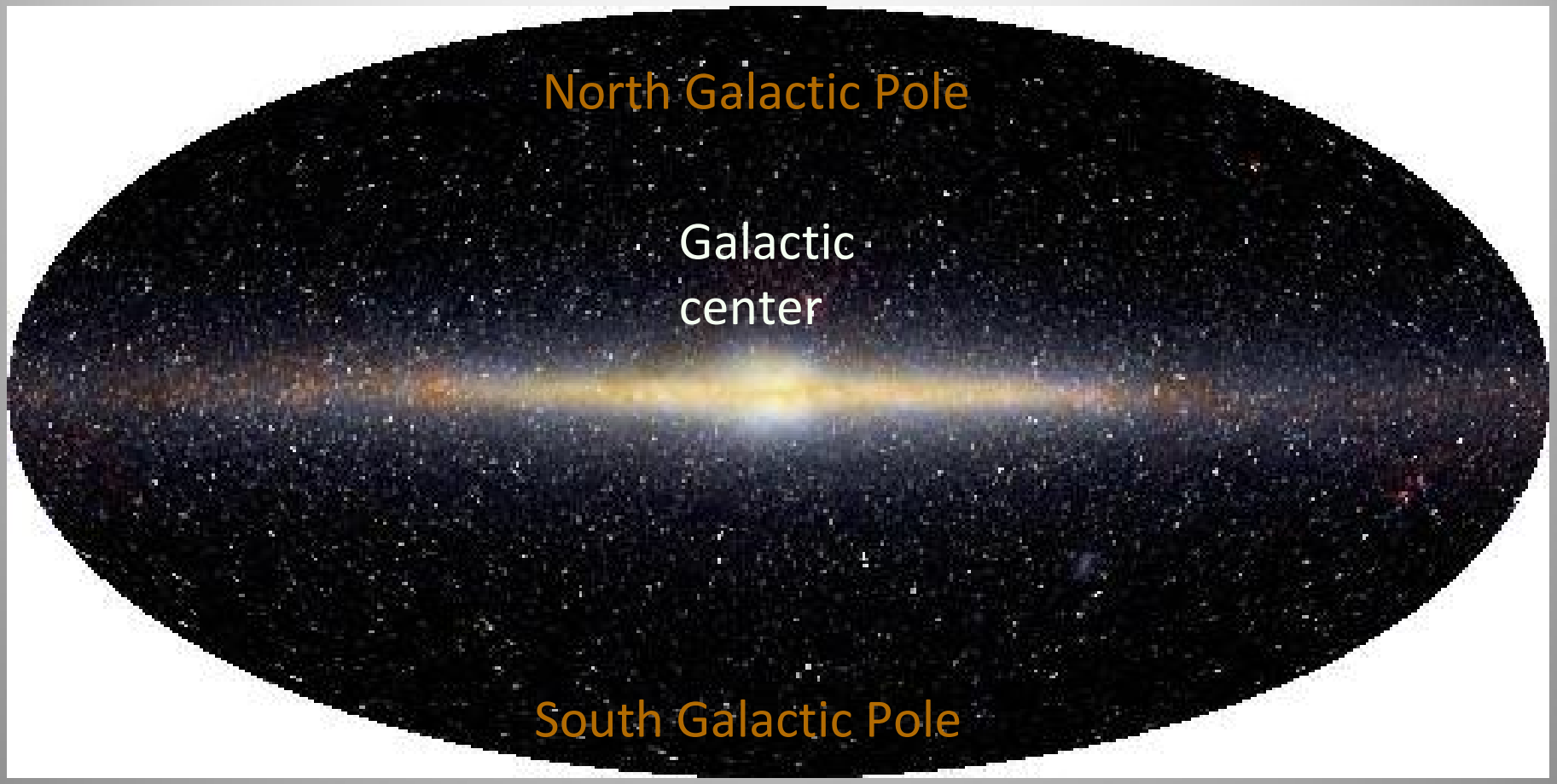
What lies at the Galactic center?



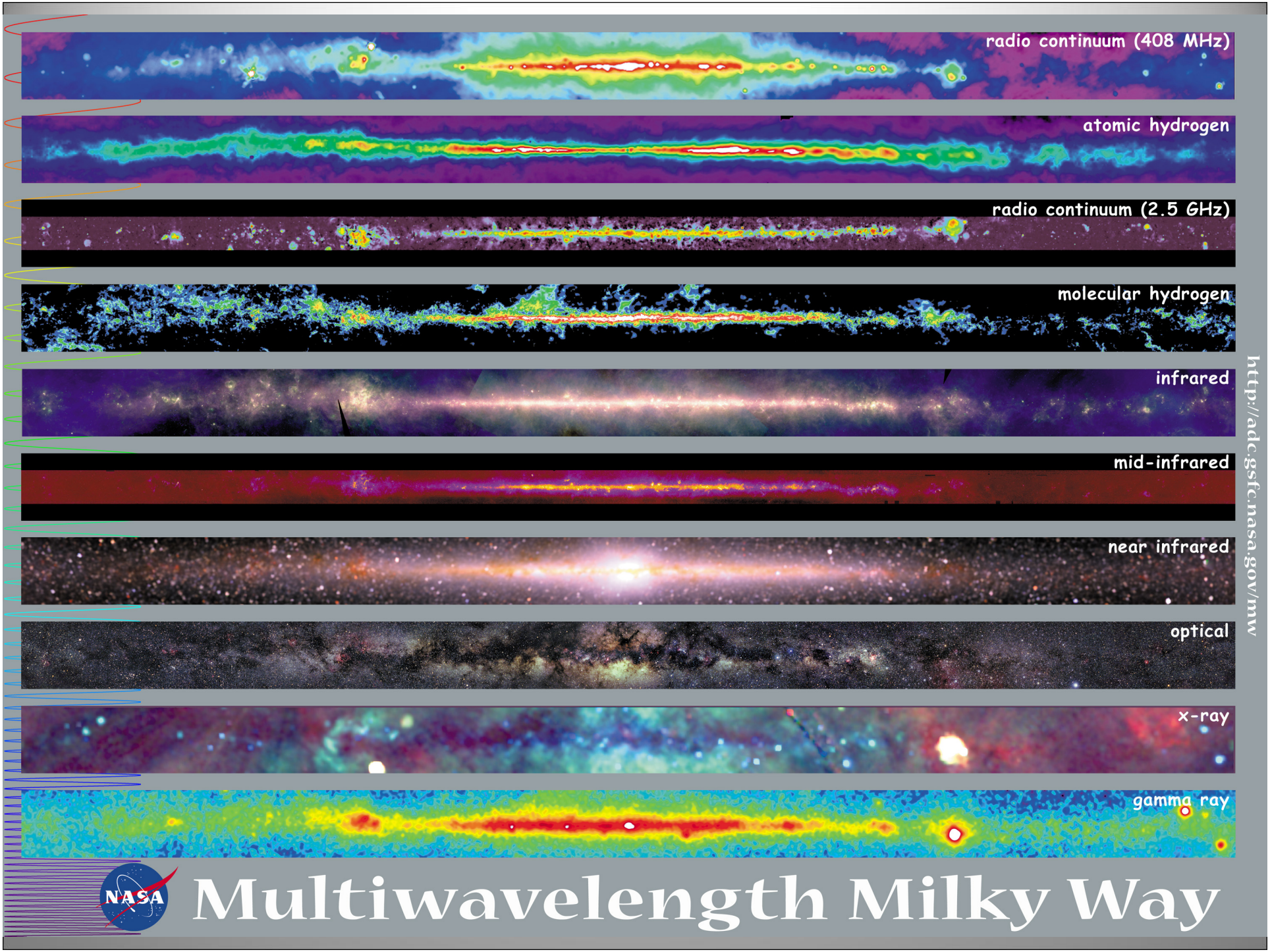
Galactic center lies in Sagittarius - can't see *anything* in visible light because too much dust in the way

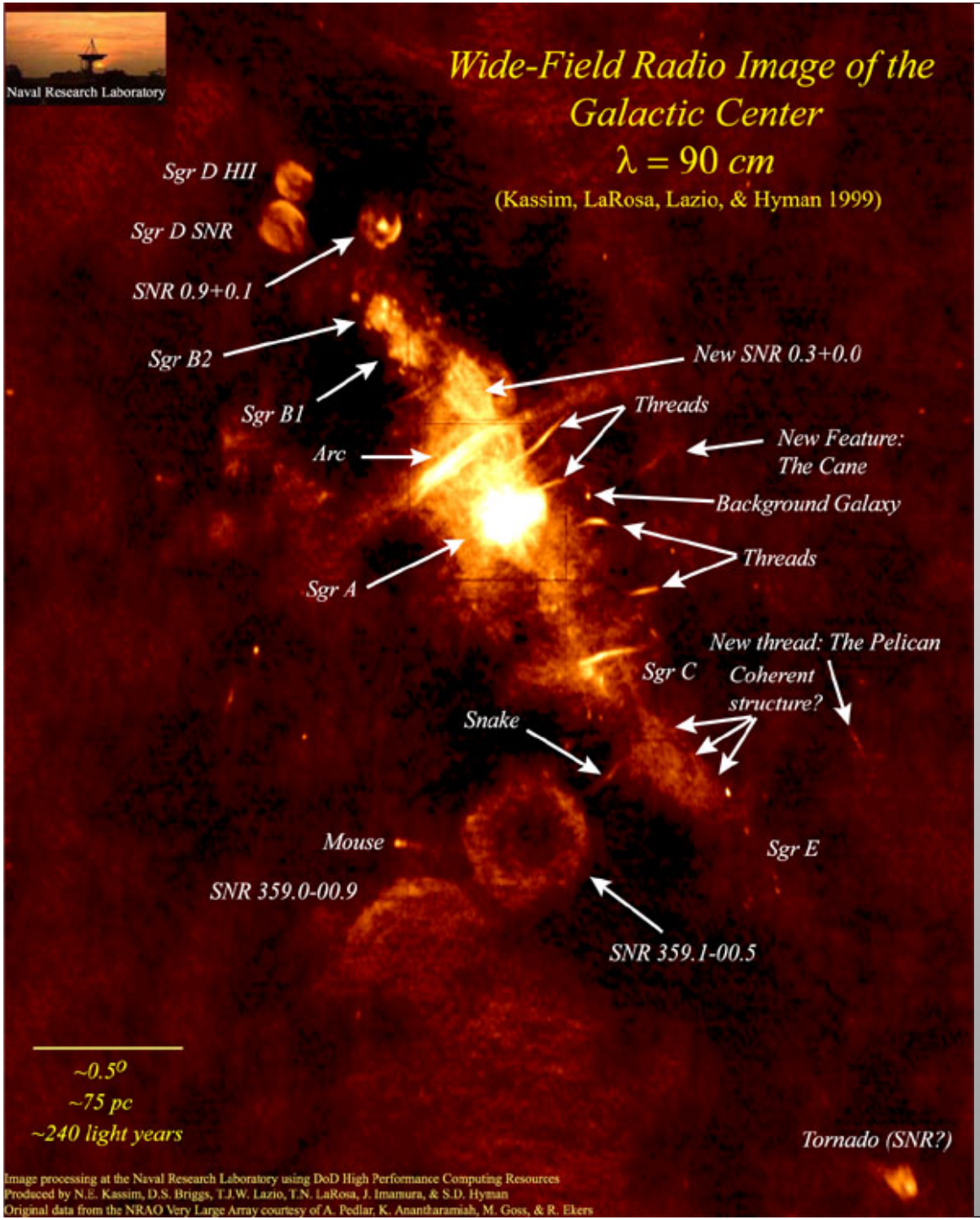
IR and radio radiation can pass through the dust more readily - show gas and stars close to the center

Best view of the Milky Way is in infra-red radiation



IR is absorbed less strongly by dust in the galaxy than optical light, so get a truer picture of what the Milky Way looks like


radio continuum (408 MHz)
atomic hydrogen
radio continuum (2.5 GHz)
molecular hydrogen
infrared
mid-infrared
near infrared
optical
x-ray
gamma ray
NASA
Multiwavelength Milky Way
http://adc.gsfc.nasa.gov/mw



Radio: see many supernova remnants (means stars must have formed there recently), plus wisps and streamers of high velocity gas

At the exact center, enigmatic radio source called Sagittarius A*

To see the stars, look in the infra-red:

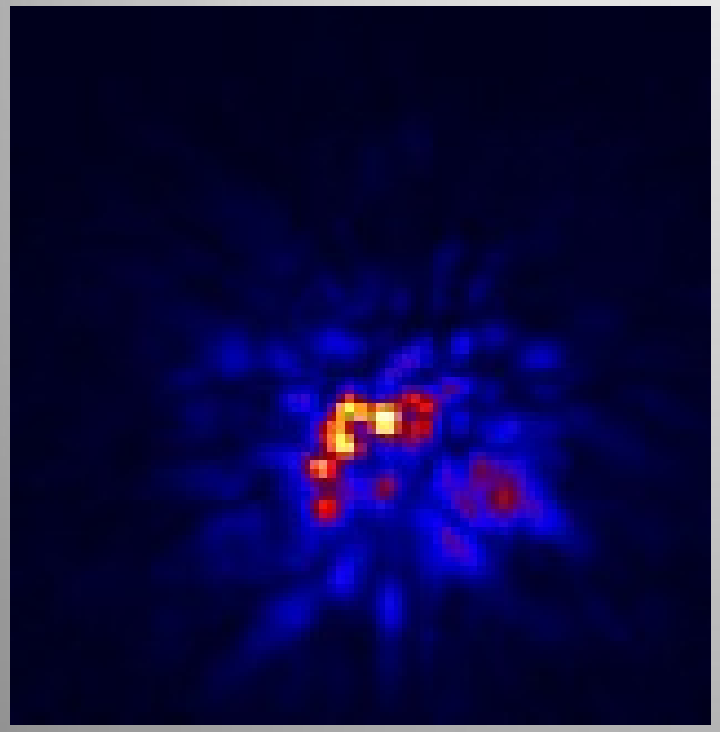
See clusters of young, massive stars

Very high density of stars packed into the central region

Velocities of the stars increase toward the position of Sgr A*

Image from the Gemini telescope

Zoom in further encounter a problem: Earth's atmosphere blurs light and smears out images of stars



Problem for all ground based telescopes - means that the *resolution* of even the largest telescope is rarely better than 1 arcsecond (1/3600 of a degree)

Can be overcome in part using *adaptive optics*

Line of sight to faint object we really want to observe

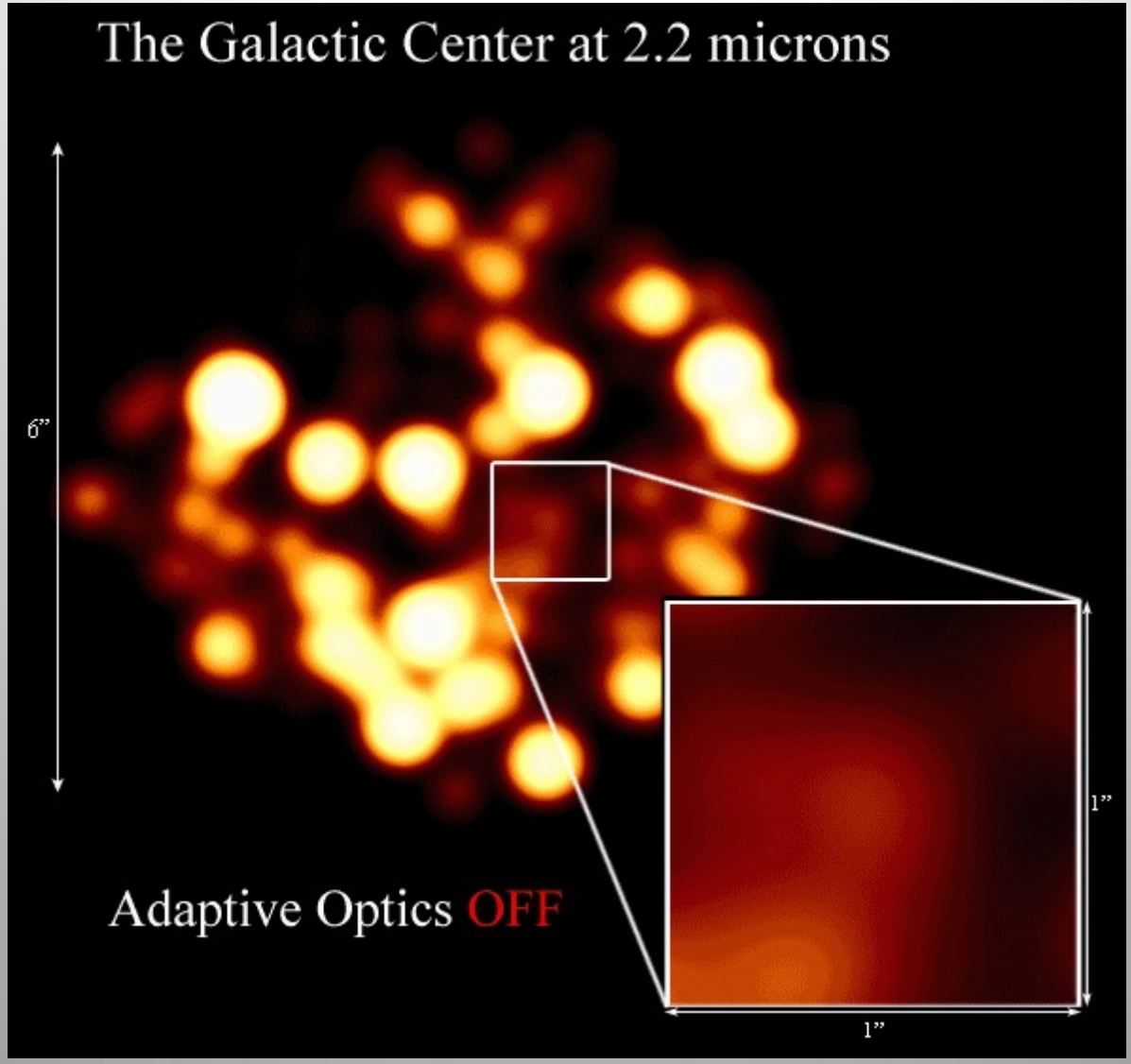
Bright star `guide star'

Idea: measure the distortion caused by the atmosphere by looking at a bright star close to the target

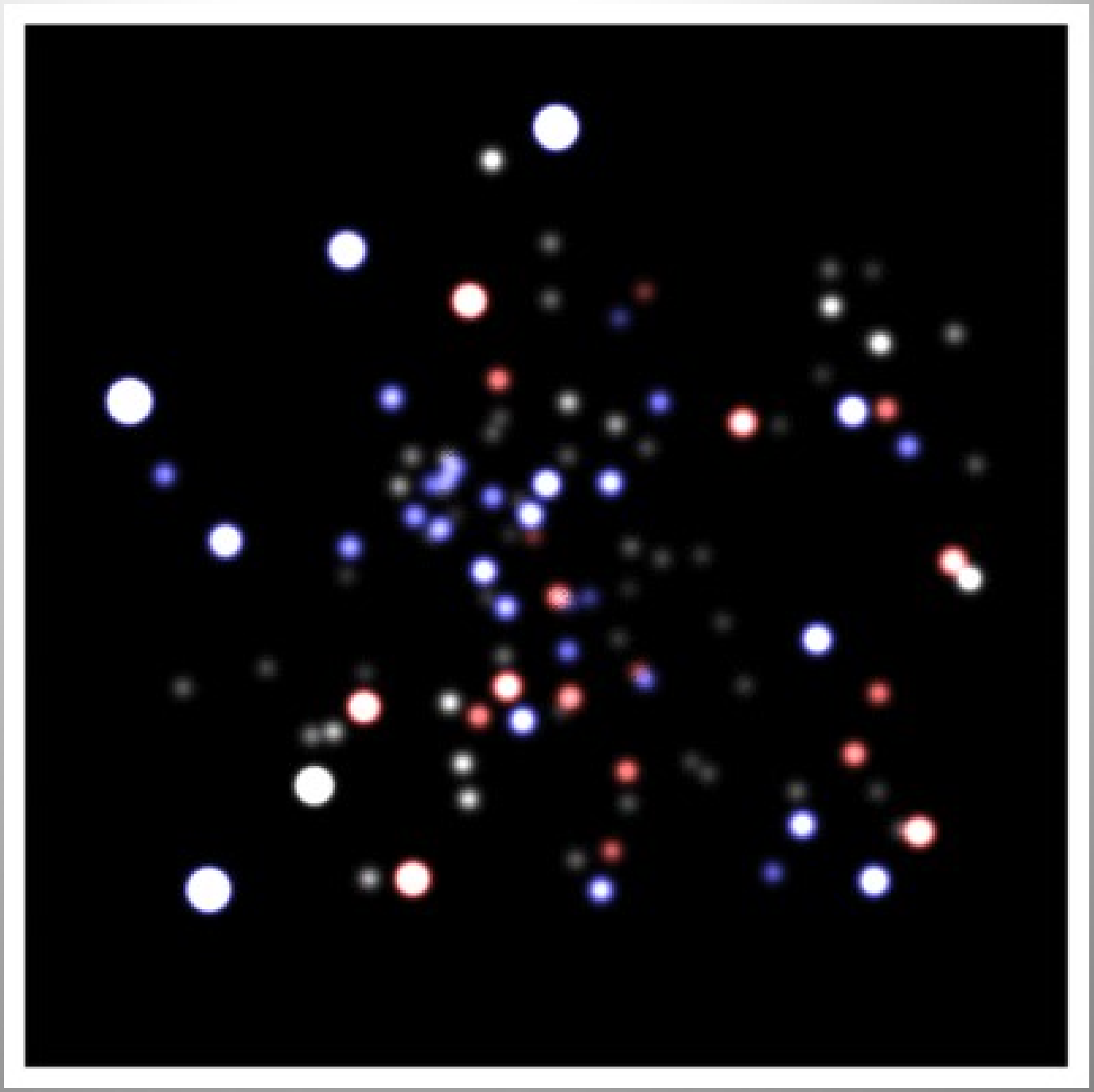
Use this to *correct* for the blurring along the line of sight to the target we're really interested in

Adaptive optics: works provided that there's a bright star close enough

If no natural star exists, can `make' one by firing
a laser close to the line of sight

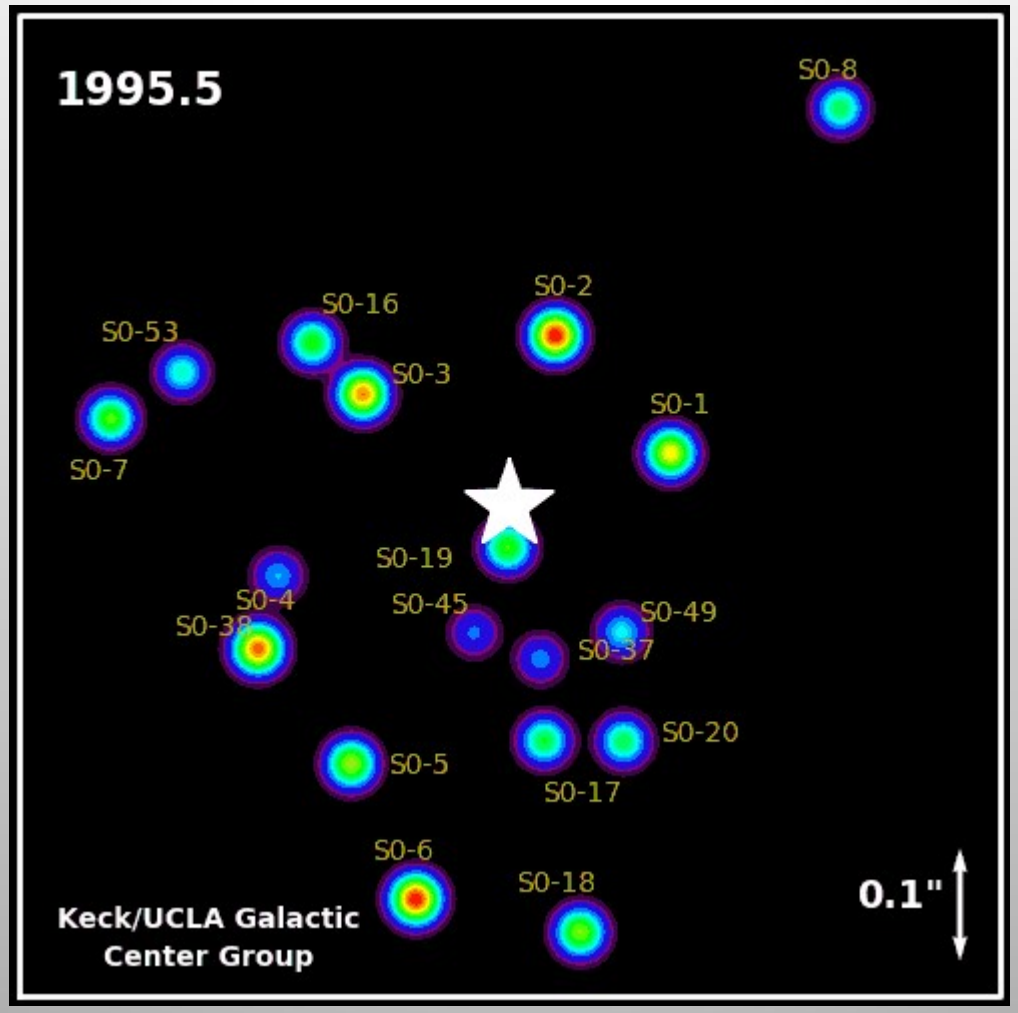


Adaptive optics provides the sharpest view to date of the star field close to the Galactic center



Genzel et al. 2008

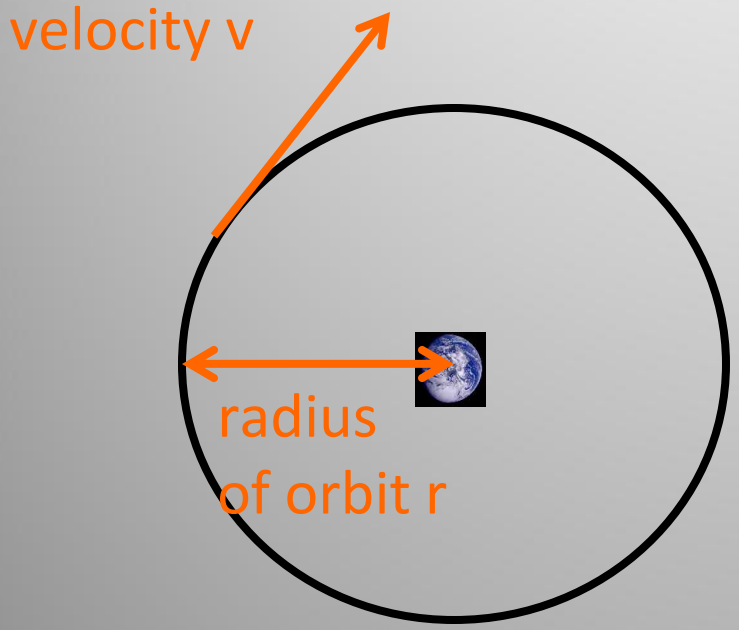
(1992-2008)



Find: the stars are orbiting at very high velocities (up to 10,000 km/s) around a dim object at the very center of the Galaxy - very probably a supermassive black hole

Measuring the mass at the Galactic center

If we know the mass M of a body, can work out how fast we need to go to orbit at distance r:



For a circular orbit:

$$v^2 = \frac{GM}{r}$$

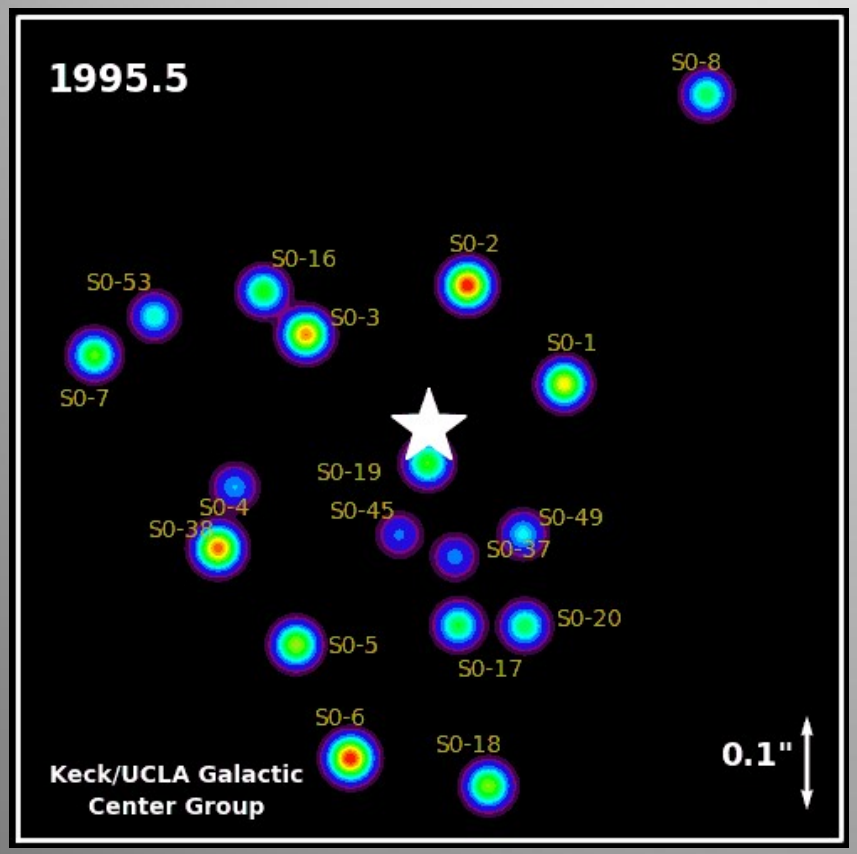
…where G is the gravitational constant. Numerically:

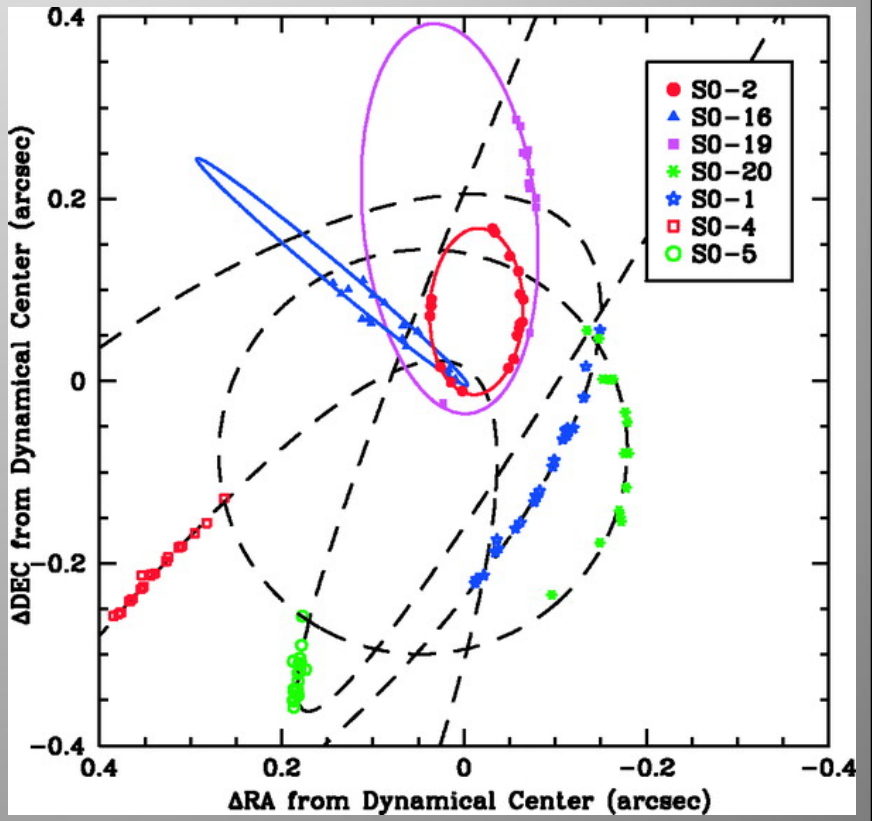
$$G = 6.67 \times 10^{-11}\ \mathrm{m}^3/(\mathrm{kg} \times \mathrm{s}^2)$$

Observations of the Galactic Center

For the stars orbiting the Galactic Center, the observables are:

- orbital period of the stars -> their <u>velocity</u>
  - <u>radius</u> of the orbit





Mass of the dark object

Rewrite the formula for velocity:

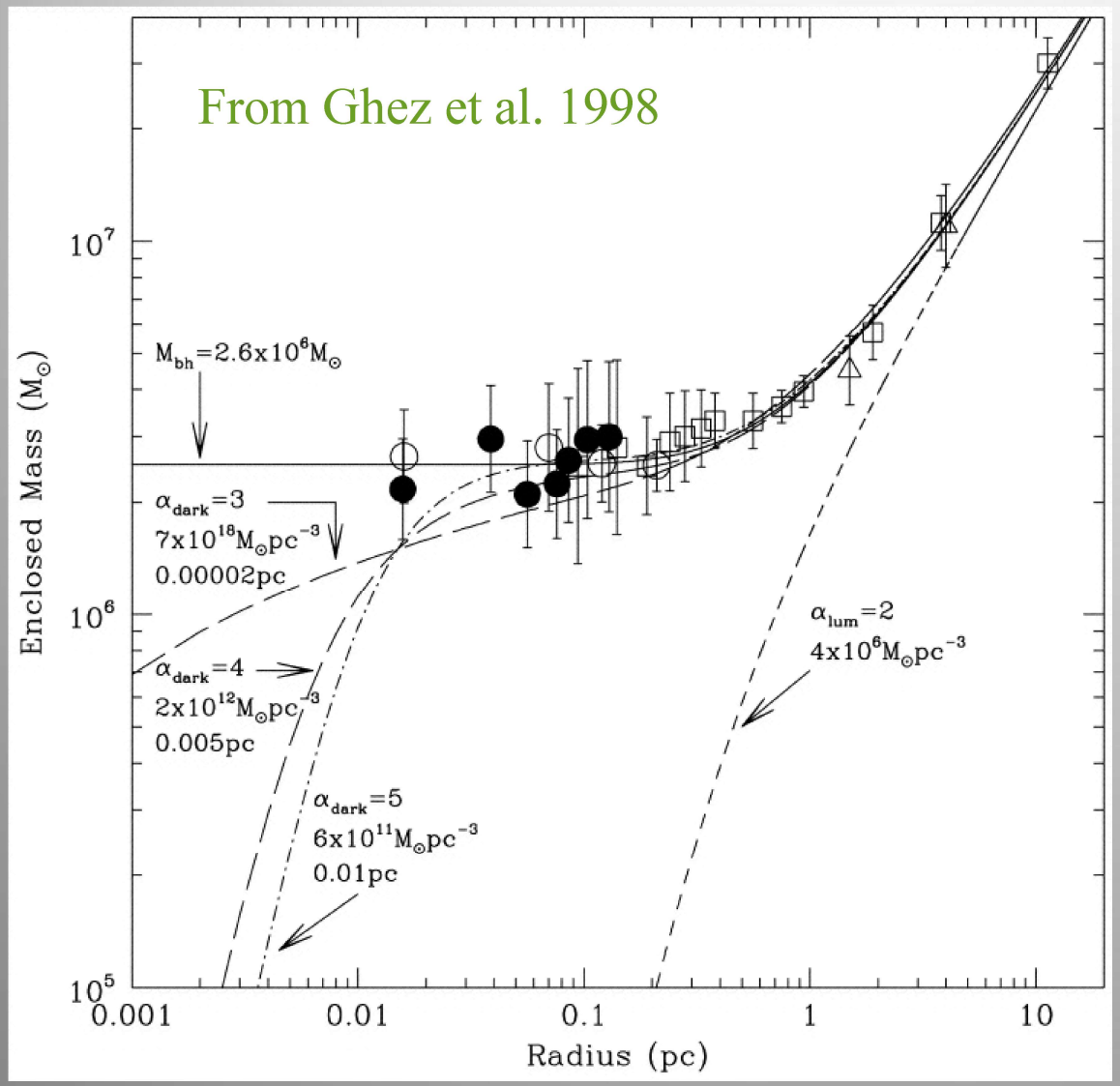
$$v^2 = \frac{GM}{r} \quad \Rightarrow \quad M = \frac{rv^2}{G}$$

Use the measured values of v and r for the star SO-2:

- v = 1.3 x 10^3 km/s
- r = 3 x 10^{11} km (2000 AU)

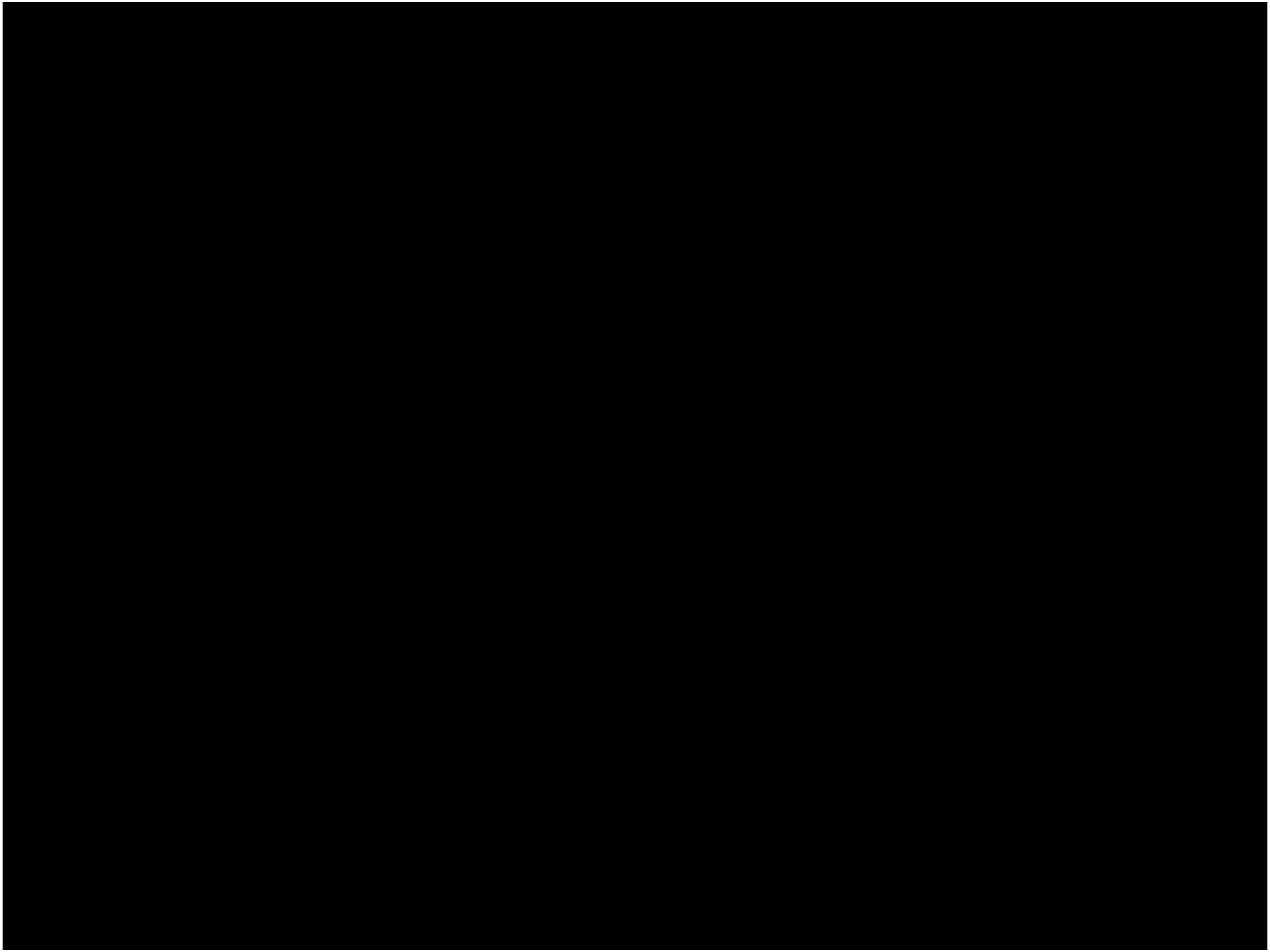
Formula gives: M ~ 4 x 10^6 Solar masses

THE MILKY WAY'S NUCLEUS



Prof. Reinhard Genzel, MPE, Munich

Prof. Andrea Ghez, UCLA



Nature of the dark object at the Galactic Center

Observations have convinced (almost) all astronomers that the unseen mass at the center of the Milky Way is a black hole:

- CANNOT be a cluster of ordinary stars - we would see the infrared light from them
- CANNOT be a cluster of stellar remnants, such as neutron stars - they would collide with each other and form a black hole very quickly
- non black hole explanations are *even weirder* than black holes!

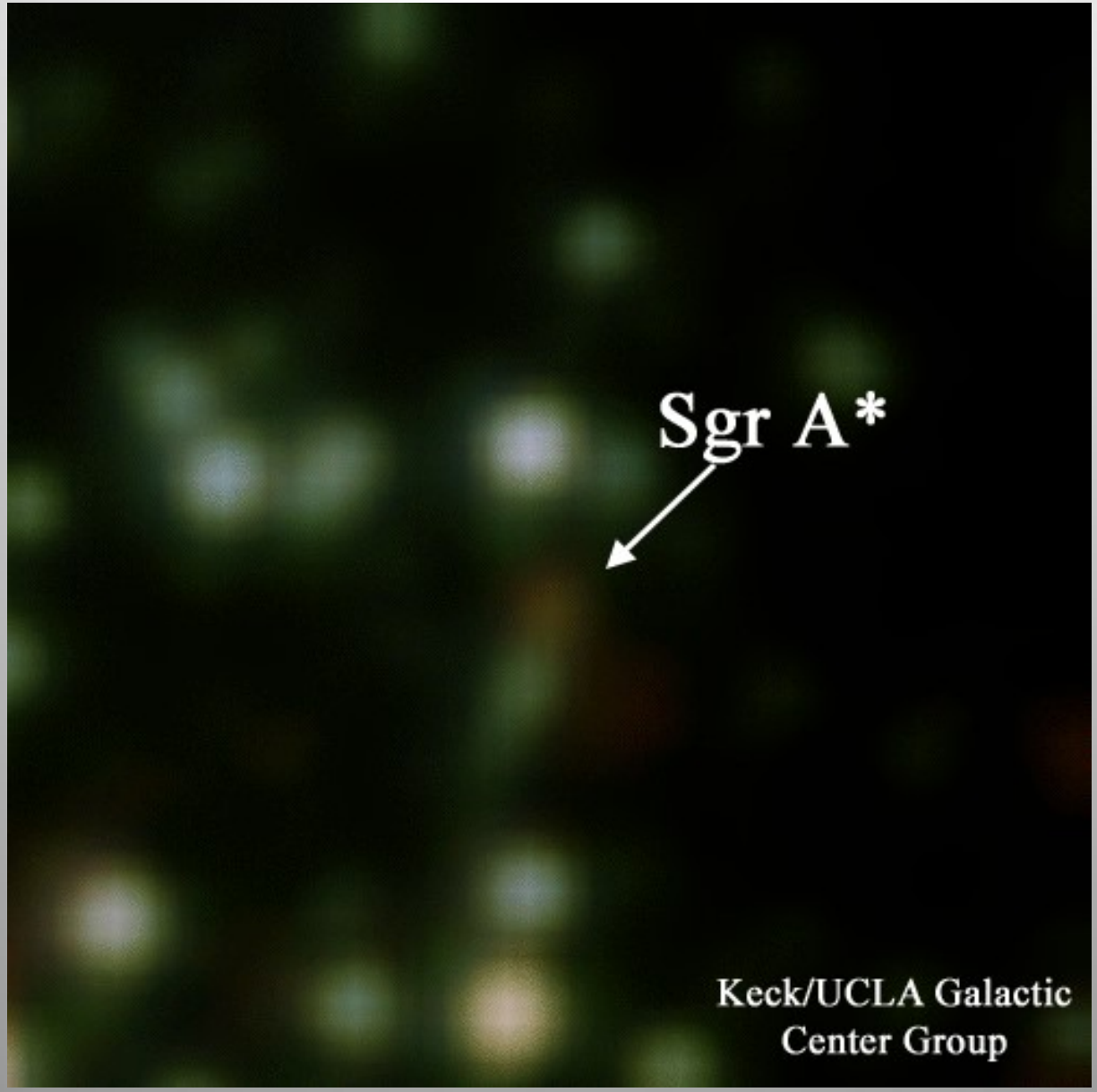
Motions of individual stars tell us where the Galactic Center supermassive BH is located…

Q: What do we see at that location?

A: A weird object called Sagittarius A-star (SGR A*)

Emission in several wavebands

- radio
- infrared
- flares in X-ray



Total power in all these bands is quite small

Black hole in the Milky Way is “quiescent”, not *currently* growing much in mass or radiating strongly due to accretion

Puzzle – plenty of gas near the black hole:

- dense molecular gas at ~few light years
- numerous young stars are losing mass in stellar winds in the black hole’s vicinity

Why is this gas not being accreted?

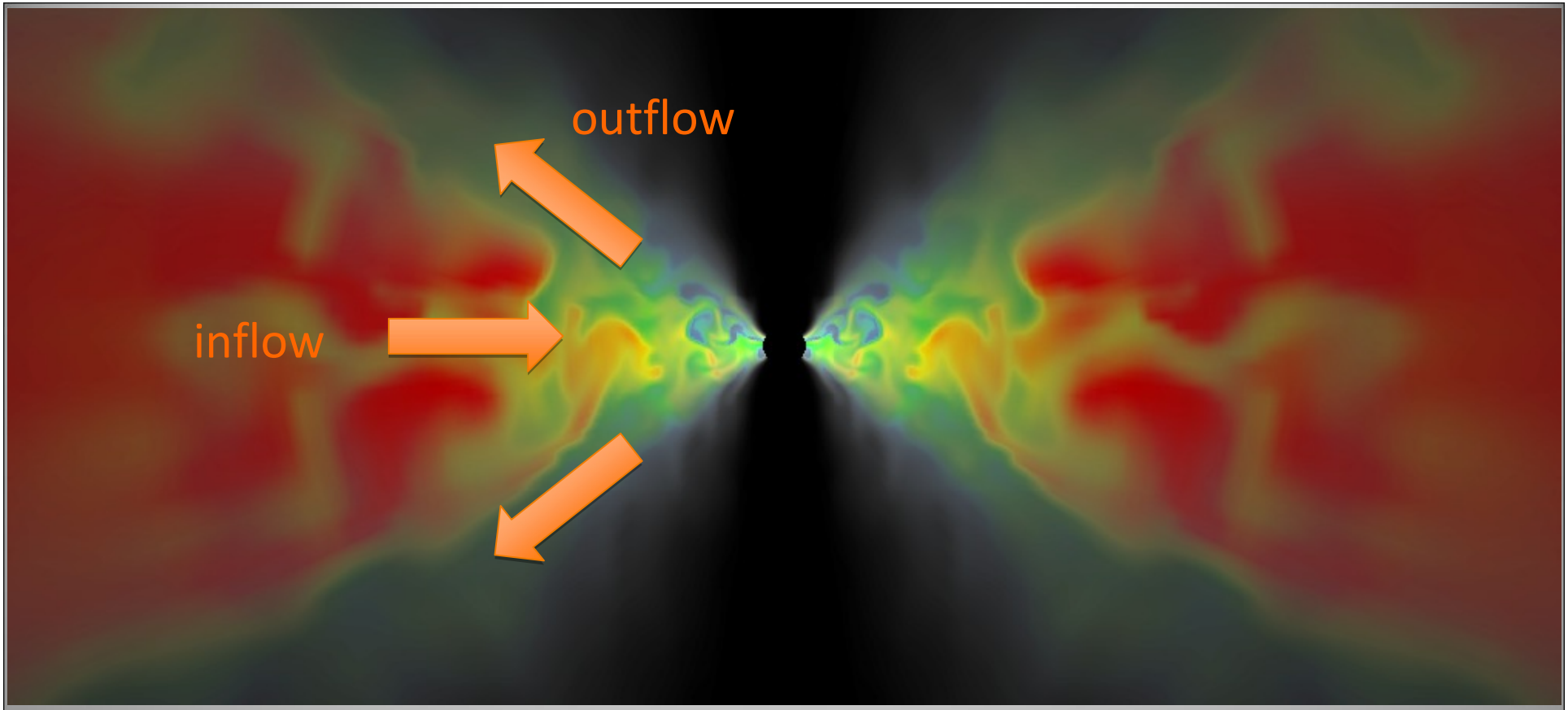
ANSWER 1: the Schwarzschild radius $R_S = 2GM / c^2$ is very small compared to the scale of these mass reservoirs

Gas has too much angular momentum to be directly accreted, how much gets accreted depends on the details of the friction ("viscosity") in the disk

Why is this gas not being accreted?

ANSWER 2: if the gas cannot cool, release of energy heats it up to extremely high temperatures

Hot gas can escape before it comes close to the event horizon



"Radiatively inefficient accretion"

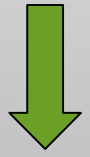
- at low accretion rates gas is low density and cannot cool – heats up
- hot gas escapes, so only a small fraction of the already weak accretion reaches hole

ENERGY CHAIN IS BROKEN:

GRAVITY

matter swirling inward

MOTION



friction

HEAT

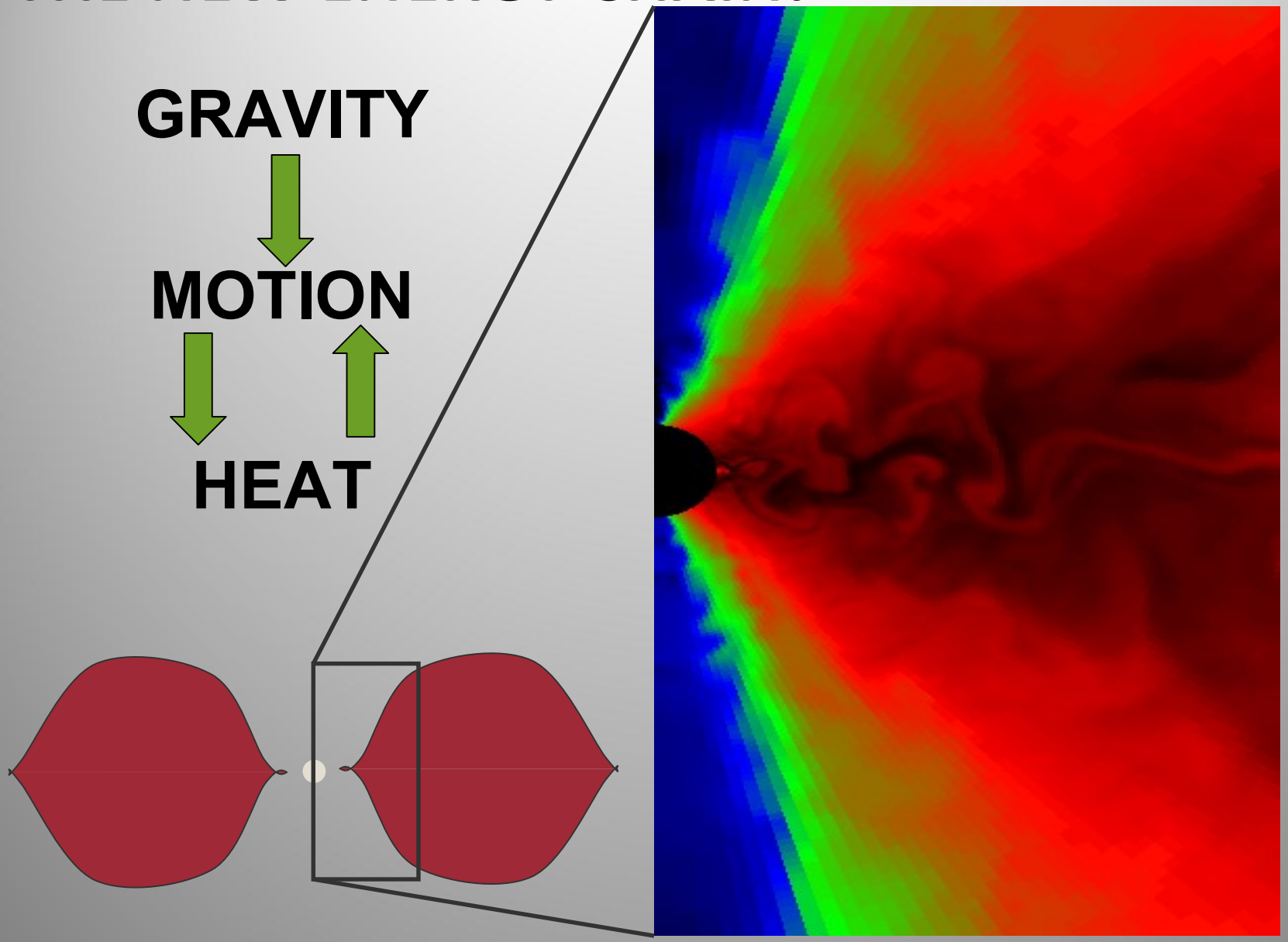
RADIATION (X-rays, UV…)

THE NEW ENERGY CHAIN:

GRAVITY

MOTION

HEAT



Black holes can be fussy eaters