AST 301
Introduction to Astronomy

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AST 301 (Lacy), course website

Astronomers welcoming a bouncing baby black hole

ASSOCIATED PRESS

WASHINGTON — Astronomers may have lucked into the ultimate in cosmic baby pictures: a voracious black hole fresh from its violent birth.

After watching the explosion of a nearby star into a supernova in 1979, astronomers now know that the star's death wasn't an ordinary one. The star's explosion was big enough to cause a black hole to develop in its wake.

They think it's a black hole because they see something steadily consuming the gassy remnants of the exploded star, which is a telltale sign of a black hole. It sucks up everything that gets too close.

And in this case it's a lot. In the past 30 years since this star was seen to explode, this baby black hole has eaten about the equivalent of the Earth in mass, which is about as big as black hole appetites can get, said Harvard University astrophysicist Avi Loeb. He's co-author of a new paper in the journal New Astronomy, and he discussed the findings at a NASA news conference Monday.

This composite image shows a galaxy where a black hole may have formed, in the area of the bright bluish-white dot in the bottom left quadrant of the image.

NASA

On a cosmic scale the mass of the Earth is not an awful lot to eat, but from Earth's point of view, it's kind of awesome, said NASA astrophysicist Kimberly Weaver.

"It's like the planet eater in 'Star Trek,'" she said.

Black holes are warped regions in space where gravity is so strong that nothing — not even light — escapes.

"It's the first time we're seeing a black hole being born in a normal supernova," Loeb said. "We're able to learn about environments that cannot be reproduced in the lab and can only be observed in the universe."

Although black holes are thought to exist throughout the universe, it is unusual to witness one from near birth that "evolves and changes into its youthful stages," said Weaver.

By continuing to follow the black hole — which is about 50 million light-years away — future astronomers will learn just how much material is left over from the star's explosion, said Dan Patnaude of Harvard, a study co-author.

"This is certainly eating as much as it can," Patnaude said. "This is working as hard as it can to gobble up that material, exactly like a teenager or a toddler."

Topics for this week

Describe the Milky Way Galaxy

Describe the Standard Candle method of determining distances and how Cepheid variable stars are used as standard candles.

Describe how astronomers measure the distribution of mass in a galaxy and what they find.

Describe the various types of galaxies and how they differ from the Milky Way.

What is Hubble's law? How is it measured, and what does it tell us about the Universe?

Standard Candle Method

We can use the formula $F = L / 4\pi d^2$ to determine the distance to a star (d) if we can guess its luminosity (L) and measure its flux: $d^2 = L / 4\pi F$

For Cepheid variable stars, we know that two stars with the same period of variation have the same luminosity.

We can determine the luminosity of a nearby Cepheid variable by measuring its distance from its parallax:

$d = 1/p$, then use $L = 4\pi d^2 F$.

Then we know that the luminosities of other Cepheid variables with the same period are the same as the luminosity of the nearby Cepheid, so we can use them as standard candles.

Groups of four

Form a group of four students.

Choose one student as the discussion leader and one as the scribe.

Answer two questions:

1. What method could you use to map out the distribution of people in this room? You can invent measurement devices, but you cannot leave your seats.
2. What difficulties or biases in your results would you encounter?

I will ask several groups to report on their methods and expected difficulties.

Distribution of Mass in the Milky Way

At least for other galaxies, we can measure the distribution of luminous matter by simply taking a picture.

But is that a fair sample of all of the matter in a galaxy?

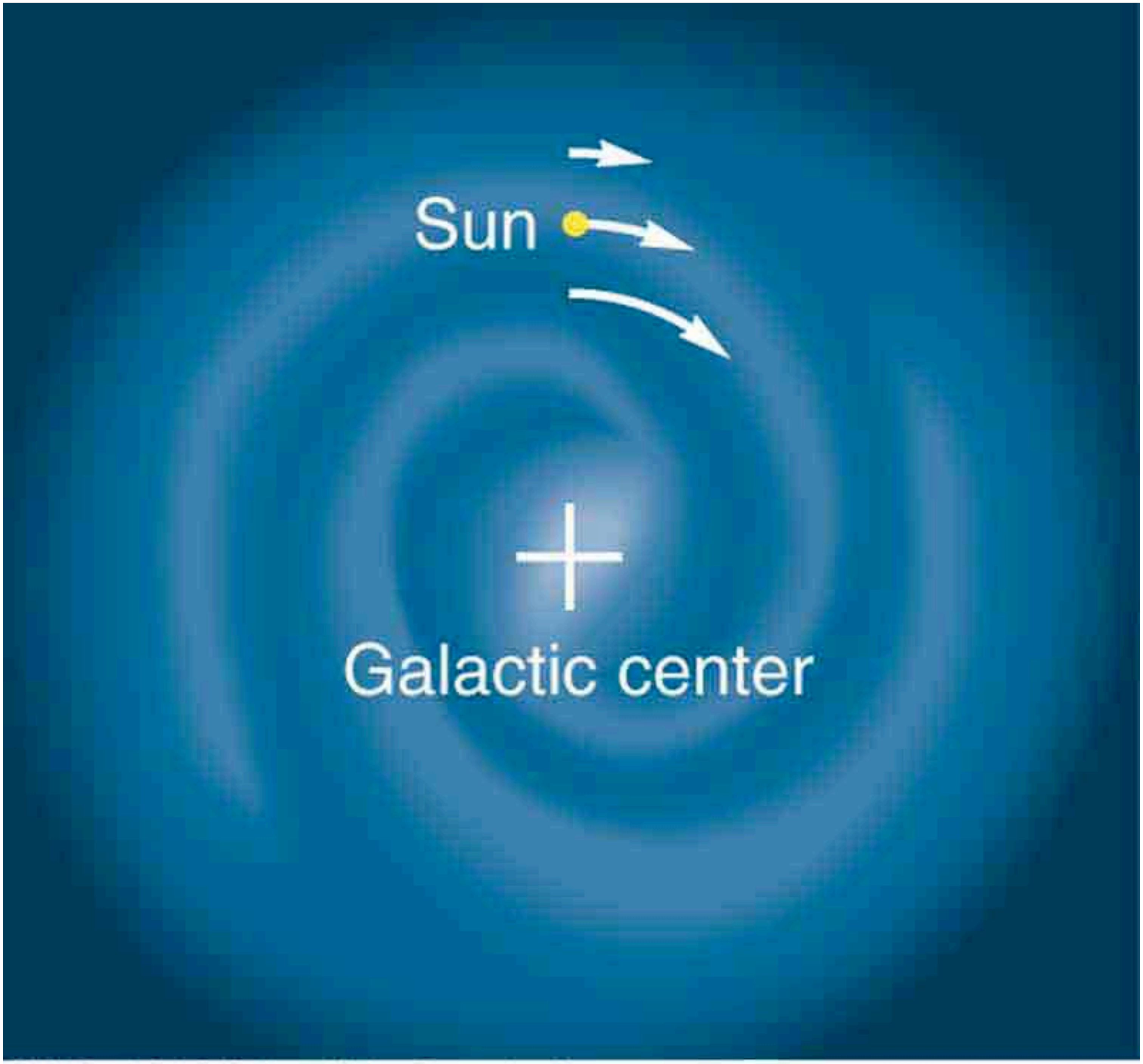
Some stars emit much more light than others.

We can measure the distribution of mass in a galaxy by observing how fast stars orbit in the galaxy.

They orbit around whatever is inside of their orbits – black holes, stars, gas, dust, ???

We can use Kepler's 3rd law to determine the mass of whatever is inside of their orbits.

M(inside orbit) = a^3 / P^2


Sun
Galactic center

There is mass where we see almost no stars

We conclude that $M_{\text{inside of radius } r} \alpha r$.

This means that there is as much mass between 11 and 12 kiloparsecs from the center as there is between 1 and 2 kpc.

This is surprising because there is much more light coming from the stars between 1 and 2 kpc from the center.

The amount of mass we calculate is also surprising.

It is several times more than the mass we calculate of the stars we can see.

Most of the mass in the Milky Way must be dark.

Mass in the center of the Milky Way

On your homework you will do a calculation I did when I was a student to determine the mass within 1 pc of the center of the Milky Way.

You should get about $3 \times 10^6\ M_{sun}$.

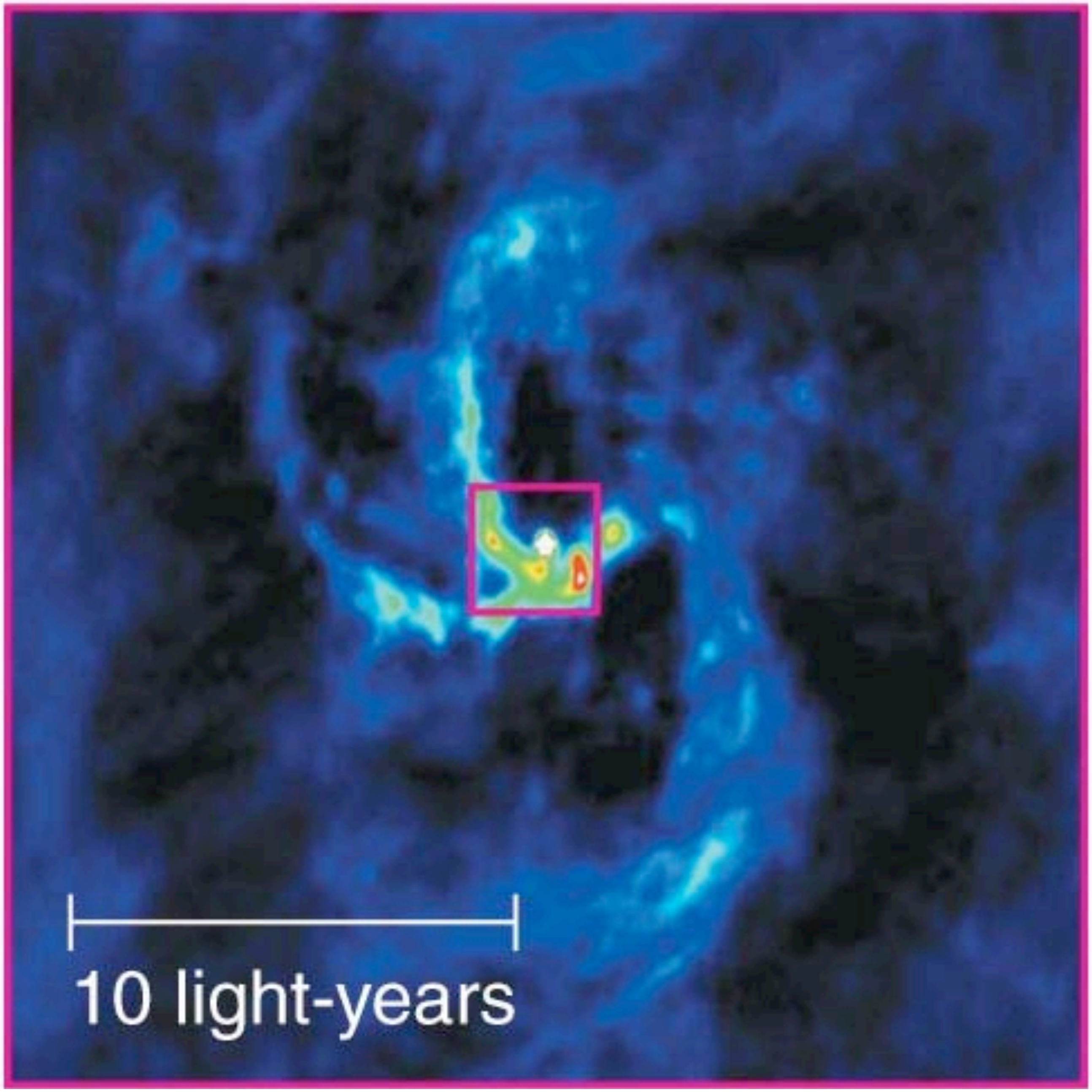
I also observed gas clouds orbiting about 0.1 pc from the center, and concluded that there was nearly $3 \times 10^6\ M_{sun}$ inside of their orbits too.

It appears that most of the mass in the center of the Milky Way is very close to the center, even though the stars are pretty uniformly spread over the central parsec.

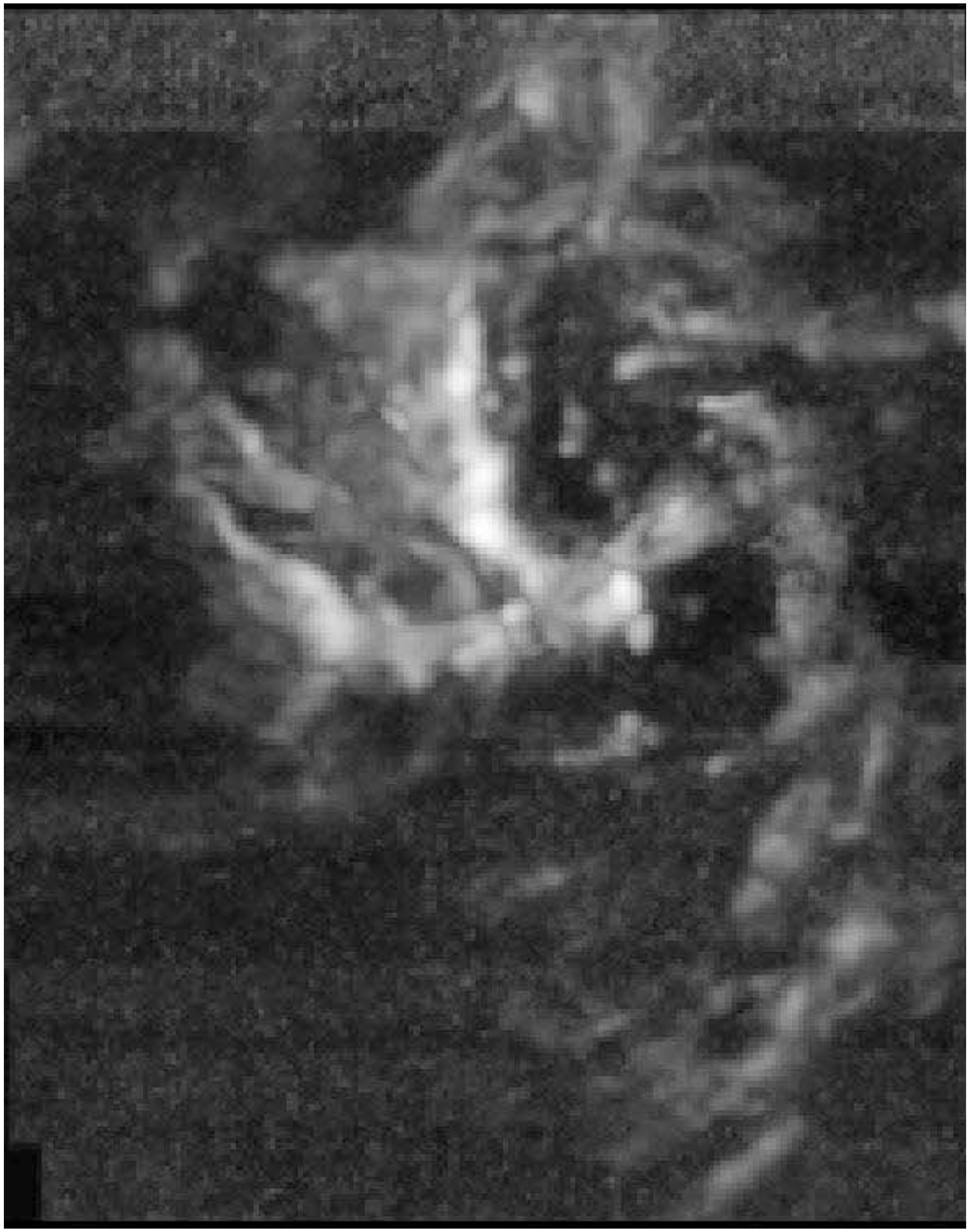
We suggested that the mass is in a $3 \times 10^6\ M_{sun}$ black hole, but we couldn't prove it.

More recent observations are more convincing.

The Center of the Milky Way (a radio picture)



The Center of the Milky Way (my infrared picture)



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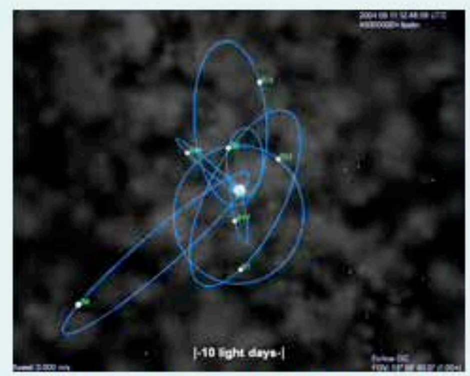

The central region of our Milky Way is an extremly interesting and fascinating field of research. Within few light years we find here ten thousands of stars forming a dense cluster, and the geometric centre of our Galaxy harbours a supermassive black hole with around 3.6 million solar masses. Due to its relative proximity of around 8 kiloparsecs, the Galactic Centre is a perfect laboratory to examine the physical processes in a galactic nucleus.

Since 1992 we have observed the central parsec of the galactic center in near infrared wavelengths. Until 2002 we mainly used our Speckle-Camera SHARP I on the NTT located at La Silla, Chile, for K band observations; since 2002 our main instrument is the adaptive optics assisted NIR-camera NAOS/CONICA at the VLT on Cerro Paranal, Chile, performing H, K and L imaging. Both facilities are operated by the European Southern Observatory (ESO).

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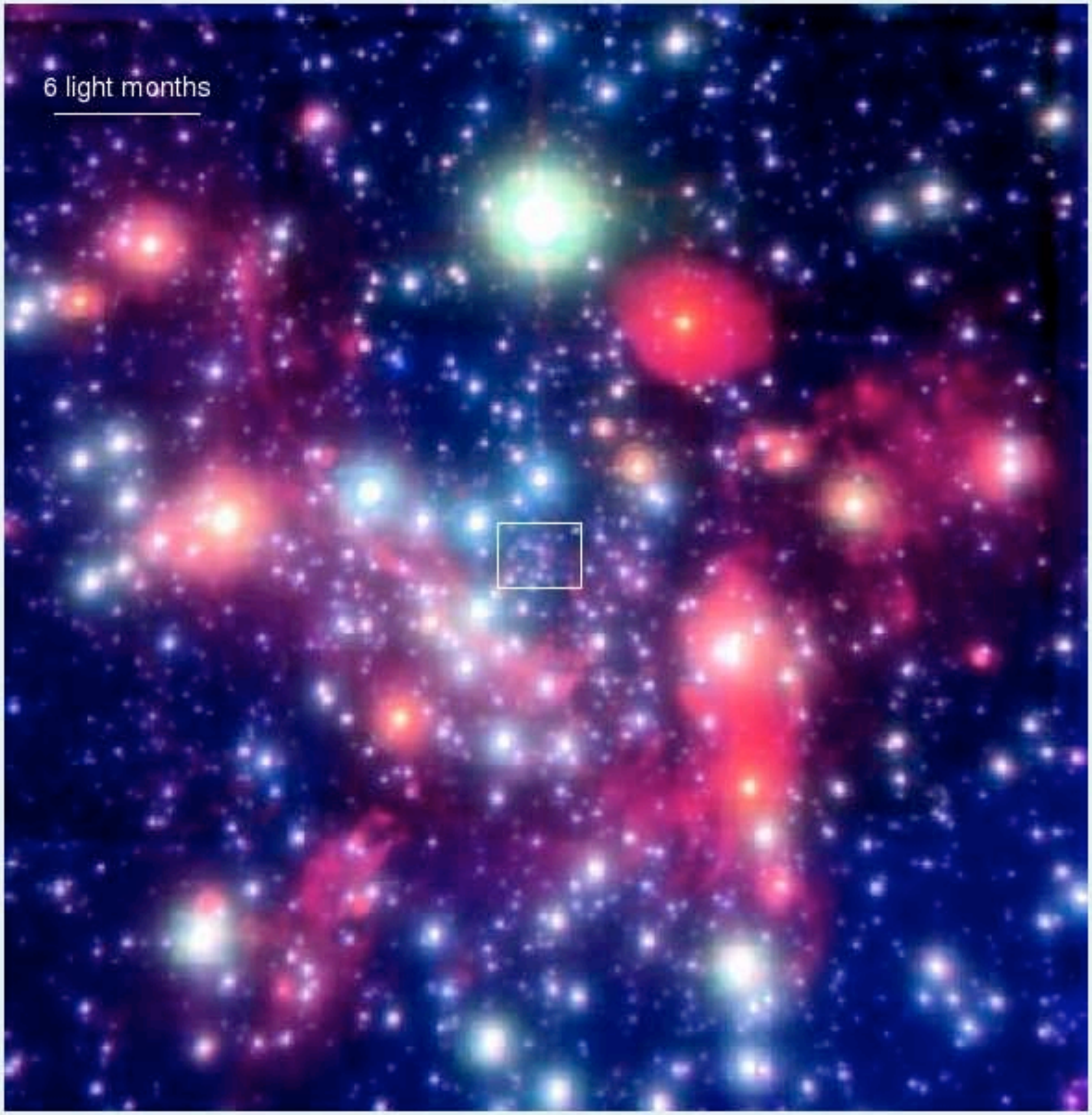
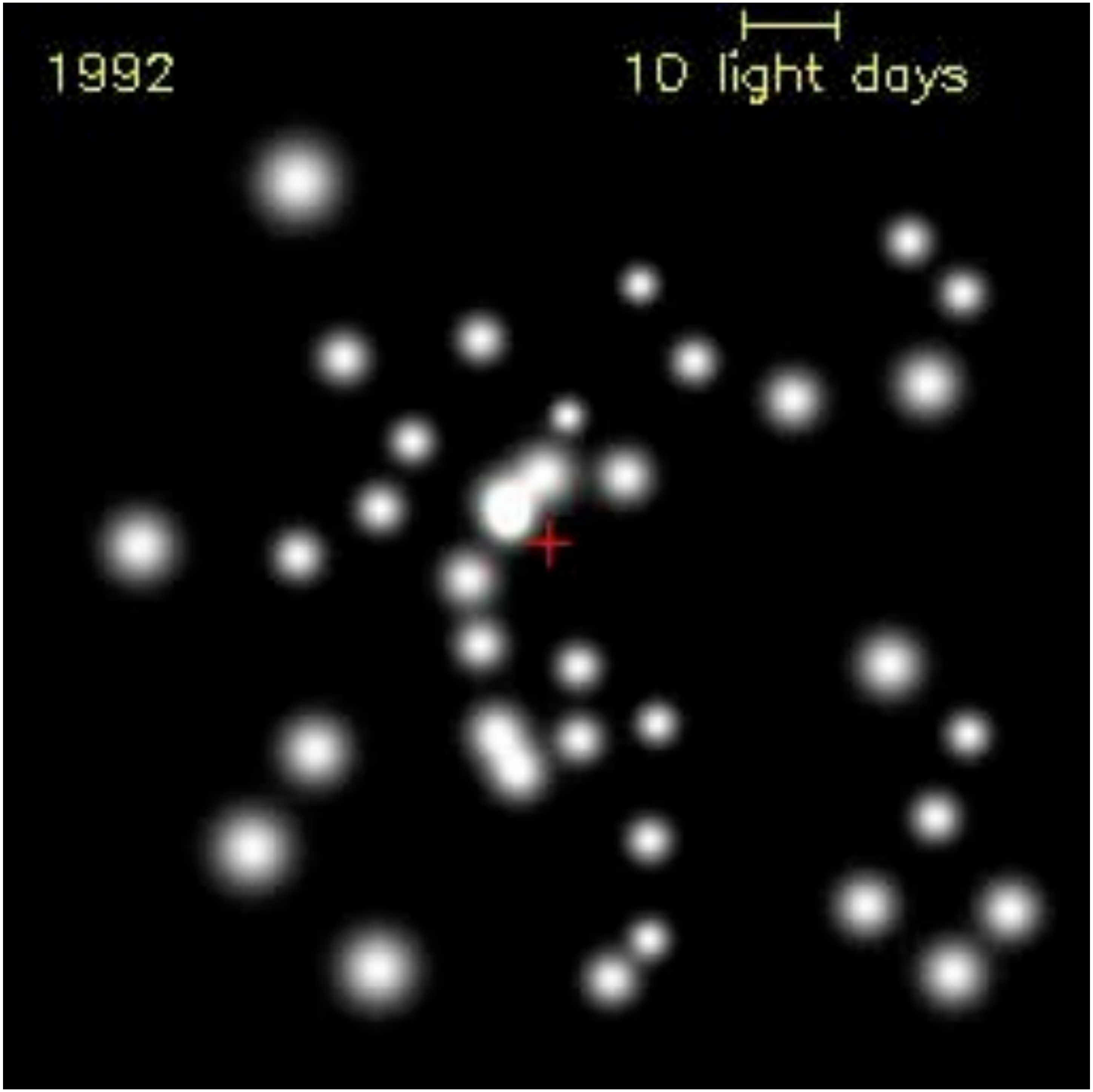
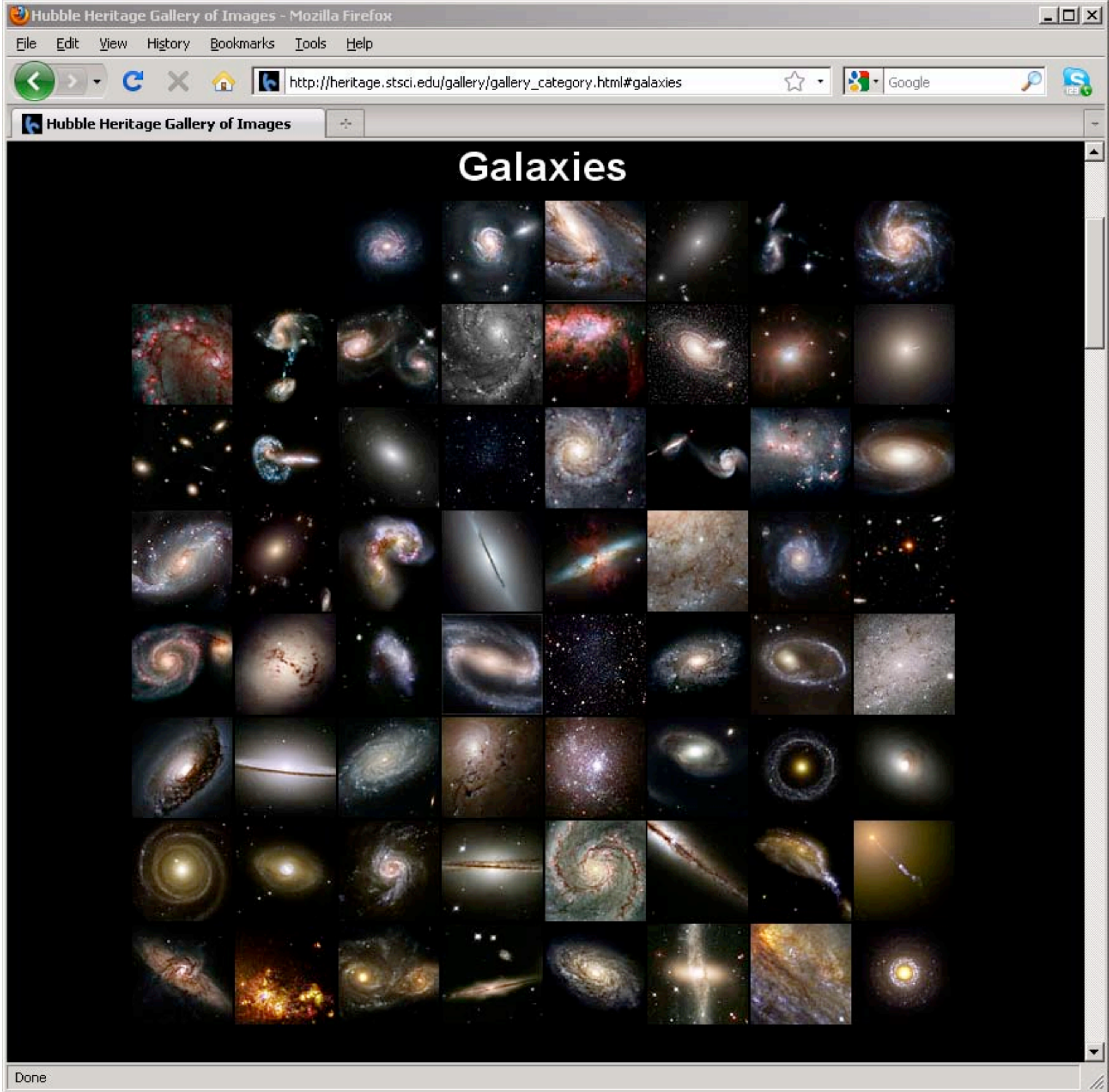


A HKL colour composite of the Galactic Centre region. The central black hole is located in the centre of the box which marks the area shown in the images above and below.


1992
10 light days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