How Do You Observe Something You Cannot See?

Prof. Andrea Ghez
Black Hole

*noun:*

an invisible area in space with gravity so strong that light cannot get out of it.
Black Hole

1. Large Gravitational Mass confined in a
2. Small volume
3. Extraordinary Efficiency of Generating Energy
4. Extraordinary Orbital Velocities around it
5. Large gravitational redshift
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Schwarzschild Radius

Black Hole
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Black Hole
X-ray “astronomy” satellite finds the brightest source in Cygnus

It’s right next to a blue giant star: the X-rays come from companion.
Giant Black Holes?

What if a Galaxy’s entire central star cluster, not just one massive star, collapsed under its mutual gravitation?

You’d end up with a Massive Black Hole (MBH), millions to billions of solar masses, inside an Event Horizon almost as big as our Solar System, millions to billions of miles across,
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Galaxy M84 Nucleus

Hubble Space Telescope

WFPC2

STIS

1500 km/s

10 l.y.
BH Plays an Important Role in Galaxy Evolution

Correlation Between Black Hole Mass and Bulge Mass

- One billion solar masses
- One million solar masses
- No black hole

Mass of central bulge: Increasing
Is there a Black Hole in our Milky Way Galaxy?
How Do You Observe Something You Cannot See?
What if the Sun disappeared today?
Why is Bigger Better in the World of Telescopes?
Bigger is Better in the World of Telescopes

**Sensitivity**
- Ability to see fainter sources
- Light gathering Increases with area of telescope mirror

**Spatial Resolution**
- Ability to see finer details
- Improves with telescope diameter
- \((\text{wavelength of light}) / (\text{telescope diameter})\)
The Galactic Center at 2.2 microns

Adaptive Optics OFF
Strehl Ratio = 0.35

$\sigma_{\text{pos}} = 100 \, \mu\text{arcsec}$

$K_{\text{lim}} = 19 \, \text{mag}$

1995 – 2004

2005 – today
Putting 20 years of data together:
A 4-Million Solar Mass Supermassive Black Hole

Keck/UCLA Galactic Center Group
10,000,000 times smaller

4 million times mass of Sun

10,000,000 times smaller volume
We Now Have Strongest Evidence for Existence of a Supermassive Black Hole in our galaxy OR any other galaxy!!!

artist's conception of Milky Way

In our galaxy OR any other galaxy!!!
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Two Tests of Einstein’s Theory of General Relativity Within Reach

- S0-2’s orbit
- Precession of the Periapse
- Emitted light ray
  - Relativistic Redshift
First Step - Relativistic Redshift During S0-2’s Next Closest Approach (Periapse) in 2018
First Step - Relativistic Redshift During S0-2’s Next Closest Approach (Periapse) in 2018
What’s in the future?
Improved Imaging Performance is Necessary for New (Fainter) Stars

Atmosphere missed by laser

Atmosphere probed by laser
Seeing Limited

UCLA Astronomy Outreach

• UCLA Planetarium Show
  – Every Wednesday night

• Astronomy Live!
  – Program for elementary schools

• Explore Your Universe
  – Science Festival for families on campus