How Big is a Supermassive Black Hole?

Boston QuarkNet June 8, 2023

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Angular Sizes – Work with a partner.

Will you thumb block the Sun? (The angular width of the Sun is about 0.533 degree.)

Measure the width of your thumb (*w*t) at the base of the nail. \_\_\_\_\_\_\_\_\_\_\_\_\_ mm

Measure the width of your little finger at the base of the nail. \_\_\_\_\_\_\_\_\_\_\_\_\_ mm

Ask your partner to measure the distance (*d*) from your right or left eye   
to your right or left, respectively, outstretched thumb (held vertically). \_\_\_\_\_\_\_\_\_\_\_\_\_ mm

To calculate the angle (degrees) subtended by your outstretched thumb   
as viewed by one eye, should you use sin-1 (*w*t/*d*) or tan-1 (*w*t/*d*) for best results?

Eye thumb

Try both. sin-1 (*w*t/*d*) = \_\_\_\_\_\_\_\_\_\_ deg. tan-1 (*w*t/*d*) = \_\_\_\_\_\_\_\_\_\_ deg.

If your thumb width uncertainty is 0.2 mm, what is the   
uncertainty of your angular width calculation? \_\_\_\_\_\_\_\_\_\_ deg.

Will your thumb or little finger block the Sun? thumb \_\_\_\_\_\_\_\_ little finger \_\_\_\_\_\_\_\_

The mean distance from Earth to Sun (1 AU) is 1.496 x 108 km.

Calculate the radius of the Sun. \_\_\_\_\_\_\_\_\_\_ x 105 km

At what distance would a U. S. quarter subtend an angle of 1 arcsec?

Diameter of U. S. quarter = 24.26 mm \_\_\_\_\_\_\_\_\_\_\_\_\_ km

Schwarzschild Radius (RS)

What combination of units for the gravitational constant (*G*), speed of light (c) and mass of an object (*M*) will yield the dimension of distance (m)? Write your answer*, e. g.* *Mc*2/*G*3, below.

The Schwarzschild radius (*R*S) defines the event horizon for a non-rotating black hole. According to Einstein’s general relativity, within *R*S spacetime is sufficiently curved that any object, and even light, in that region is unable to cross the event horizon. For an object of mass *M*.

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Calculate *R*S for a black hole of 1 solar mass.   
*G* = 6.67 x 10-11 m3/(kg s2) *M*Sun = 1.989 x 1030 kg = 2 x 1030 kg \_\_\_\_\_\_\_\_\_\_\_\_\_\_ km

Supermassive Black Holes Sgr A\* and M87

The mass of the supermassive black hole Sgr A\* at the center of   
our Milky Way galaxy is about 4 x 106 *M*Sun. Calculate *R*S for Sgr A\*. \_\_\_\_\_\_\_\_\_\_\_\_\_\_ km

How does *R*SSgrA\* compare with the radius of our Sun? \_\_\_\_\_\_\_\_\_\_\_\_\_\_ *R*Sun

Calculate the distance to Sgr A\* (about 25,650 ly). \_\_\_\_\_\_\_\_\_\_\_\_\_\_ km

1 light year (ly) = (3 x 105 km/s) x (3.16 x 107 s/yr)

Calculate the diameter of Sgr A\* in microarcseconds (mas) \_\_\_\_\_\_\_\_\_\_\_\_\_\_ mas

Calculate the angular size of an apricot (about 40 mm wide) on the Moon,   
as viewed from Earth? Earth-Moon distance = 3.84 x 105 km \_\_\_\_\_\_\_\_\_\_\_\_\_\_ mas

The supermassive black hole at the center of the supergiant elliptical   
galaxy M87 in the Virgo galaxy cluster has a mass of about 6.5 x 109 *M*Sun.

Calculate *R*S for the M87 supermassive black hole. \_\_\_\_\_\_\_\_\_\_\_\_\_\_ km

How does *R*SM87 compare with 1 AU? \_\_\_\_\_\_\_\_\_\_\_\_\_\_ AU

Calculate the distance to M87 (about 54 x 106 ly). \_\_\_\_\_\_\_\_\_\_\_\_\_\_ km

Calculate the diameter of the M87 black hole in mas \_\_\_\_\_\_\_\_\_\_\_\_\_\_ mas

The diffraction limited angular resolution (*q*) of an optical instrument is approximately  
sin(*q*) = *l*/*W*, where *l* is the observing wavelength and *W* is the instrument aperture width.

Calculate *W* for a desired resolution of 20 mas and *l* = 1.3 mm. \_\_\_\_\_\_\_\_\_\_\_\_\_\_ km

Earth diameter = 12.8 x 103 km