The Africa Millimetre Telescope

the vital link in imaging the Galaxy's supermassive blackhole

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African mm-Wave Telescope

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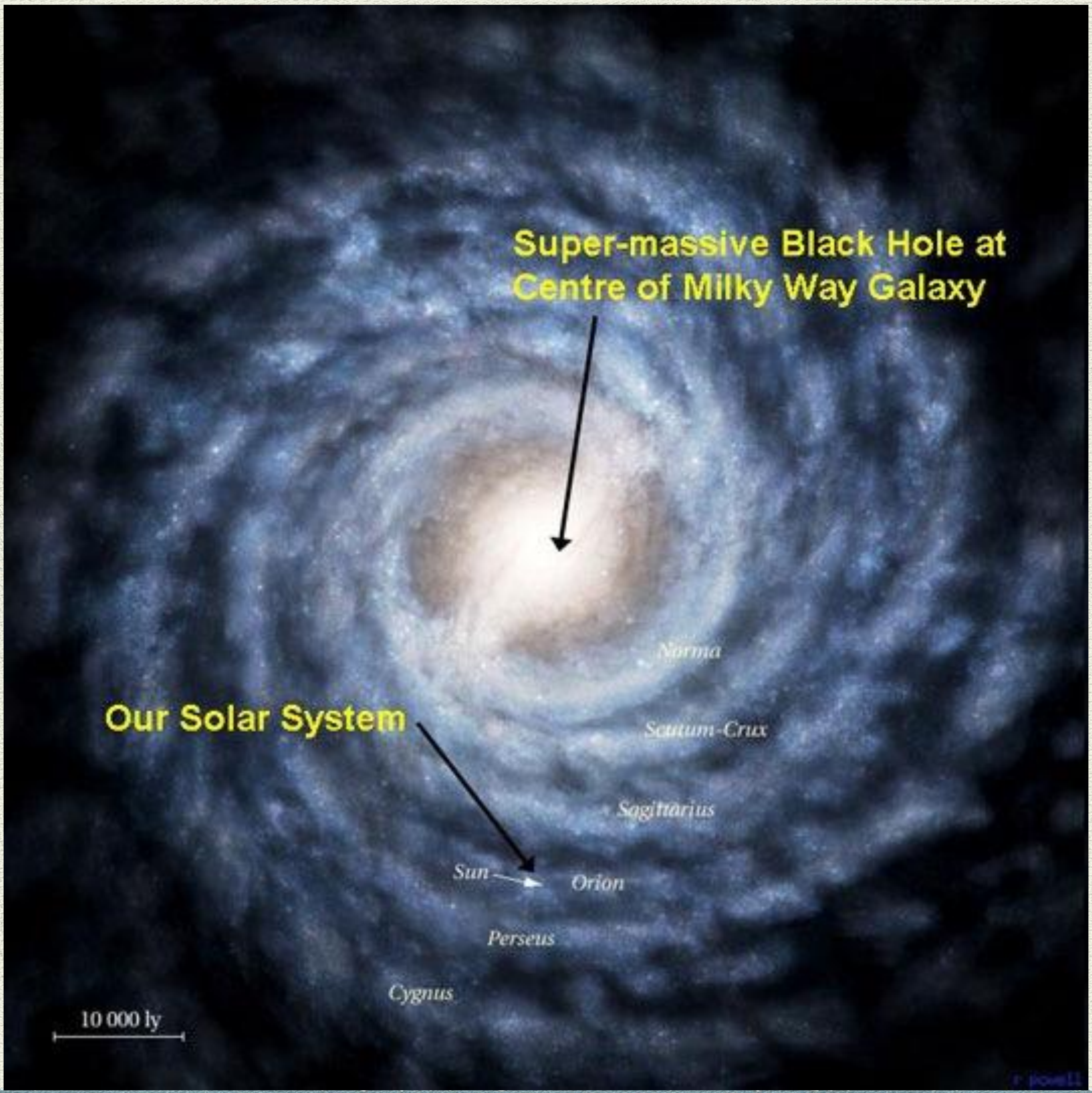


Summary of my talk

- What is a black hole?
- What is the event horizon of a BH?
- What is the evidence for a supermassive Black Hole at the centre of the Milky Way?
- How can we image the event horizon?
- The Africa Millimetre Telescope

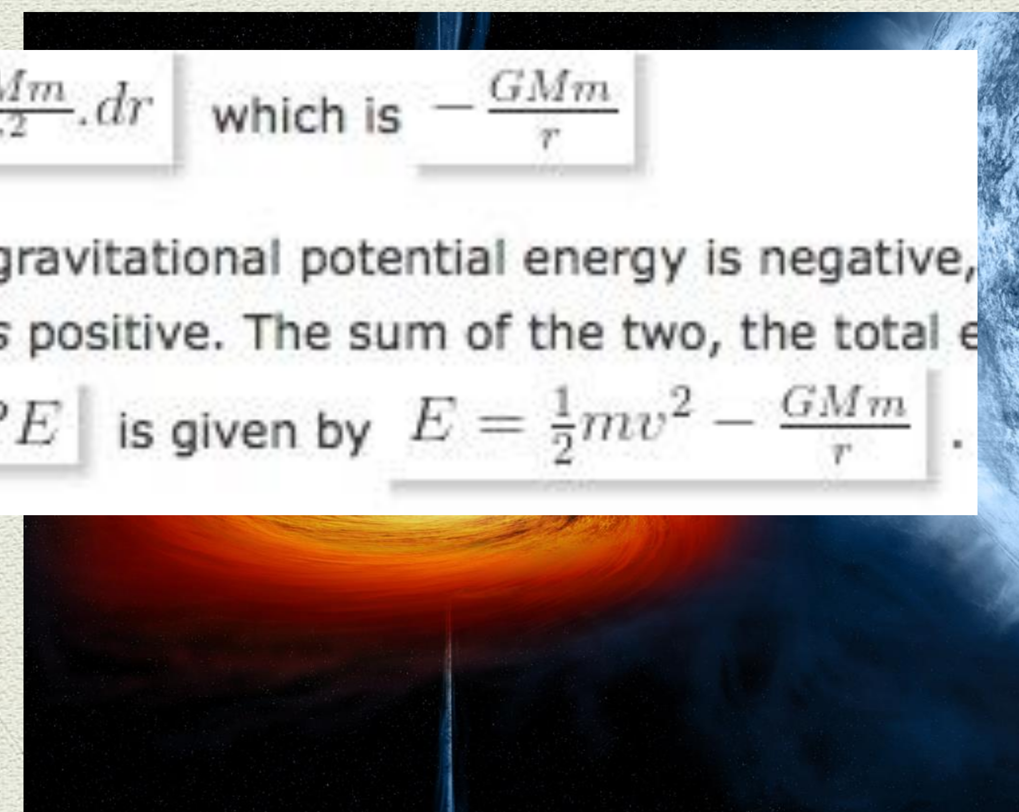
What is a black hole?

- First proposed by John Michell in 1783-84
- Every object has an escape velocity
  - For the Earth, it is 11 km/s
  - For a neutron star, it is about 0.8c
  - The event horizon is where $v_{esc} = c$
- In 1916 Karl Swarzchild worked out the solution to GR for a black hole
- The "Swarzchild radius" is the same as the "event horizon"

$$v_{esc} = \sqrt{\frac{2GM}{R}}$$

$PE = -\int \frac{GMm}{r^2}.dr$ which is $-\frac{GMm}{r}$

Notice that the gravitational potential energy is negative, energy is *always* positive. The sum of the two, the total e $E = KE + PE$ is given by $E = \frac{1}{2}mv^2 - \frac{GMm}{r}$.



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BHs at the centres of galaxies

BLACK HOLES

M. J. Rees
University of Cambridge
(the first of a series of specially solicited review articles)

It was over 40 years ago that Chandrasekhar calculated an upper limit to the mass of a white dwarf star. This result was specially startling because

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to explain energetic events such as quasars. Most interpretations of quasars and related objects involve either a single supermassive object of $\gtrsim 10^6 \mathcal{M}_\odot$, or else a very dense cluster of stars, perhaps so closely packed that stellar collisions occur frequently. The timescale of the violent activity associated with the quasar phenomenon is generally estimated to be between 10^6 and 10^8 years. Therefore, dead quasars probably vastly outnumber the living ones, and may indeed be as common as normal galaxies. Moreover, whichever type of model one prefers, the most likely endpoint of a quasar would seem to be in a massive black hole. If we regard quasars as hyperactive galactic nuclei, then a black hole might lurk in the centres of most normal galaxies. Such objects, swallowing gas from their surroundings, would give rise to

1974 - The Observatory

- In 1964 ... rgy output f ... ue to a superm...
- In the e... s and co-workers...

The discovery of Sag A*

THE ASTROPHYSICAL JOURNAL, 194:265–270, 1974 December 1

INTENSE … IN THE GALACTIC CENTER

Lick Observatory … physics, University of California, Santa Cruz

…WN
… Observatory*
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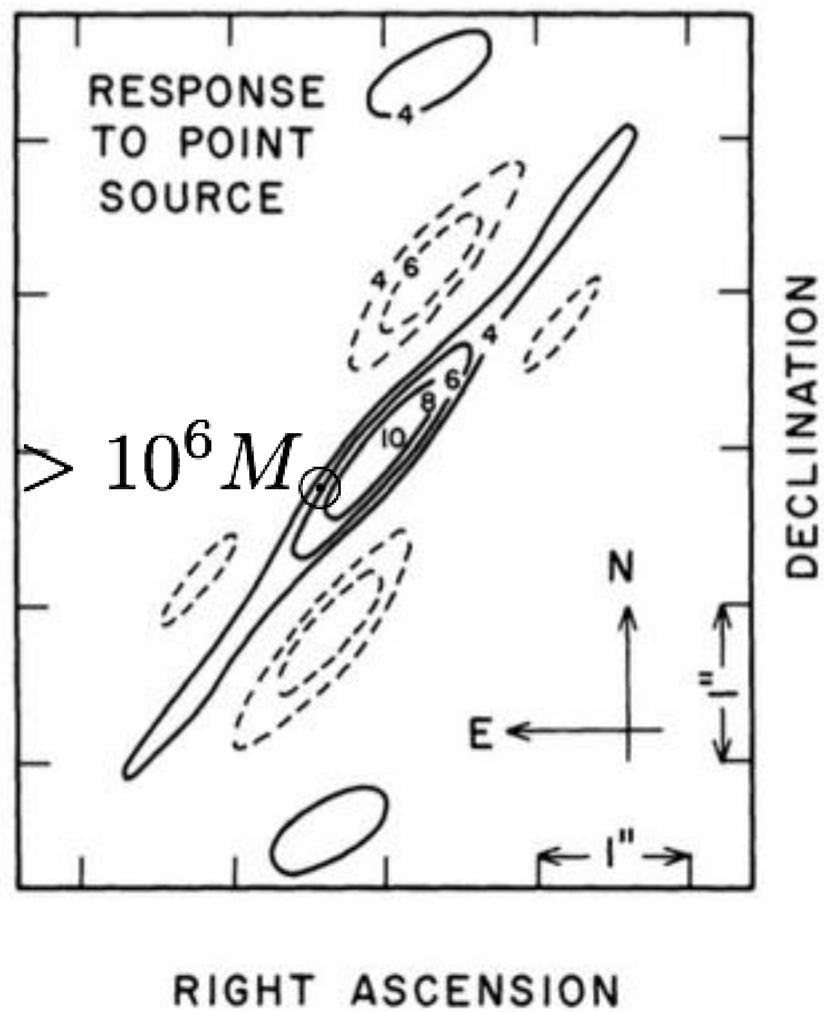
The detection of … nner 1-pc core of the galactic nucleus is reported. The structure is bri… esolved ($\theta \lesssim 0''.1$), and distributed within a few seconds of the brig… iously.

Subject headings: g…



$M > 10^6 M_\odot$

Brown using the VLA in New Mexico

Sag A* discovery image,
at 8085 MHz using the VLA

8085 MHz=3.7cm

Stellar motions

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THE ASTROPHYSICAL JOURNAL, 689:1044–1062, 2008 December 20

THE ASTROPHYSICAL JOURNAL, 692:1075–1109, 2009 February 20 doi:10.1088/0004-637X/692/2/1075

MONITORING STELLAR ORBITS AROUND THE MASSIVE BLACK HOLE IN THE GALACTIC CENTER

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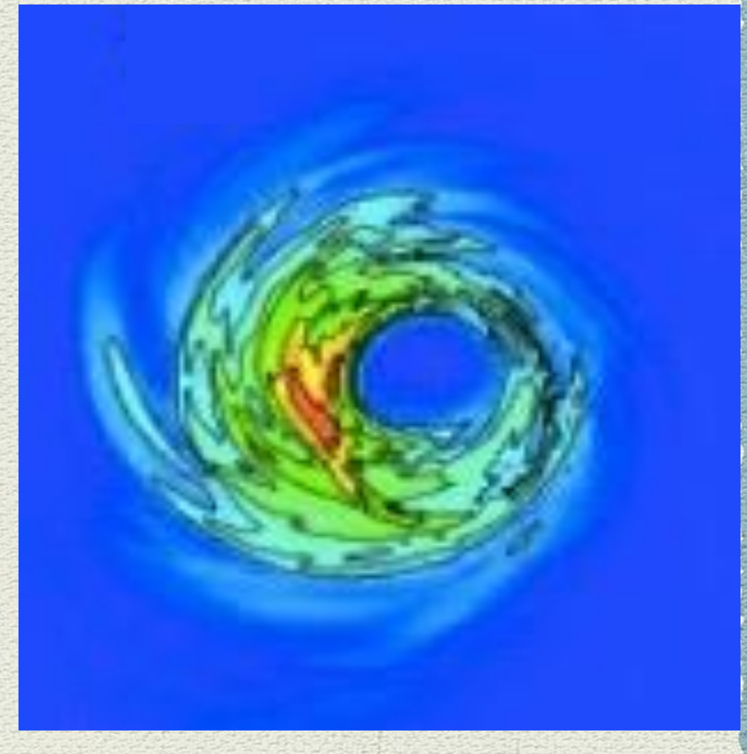
ABSTRACT

We present the results of 16 years of monitoring stellar orbits around the massive black hole in the center of the Milky Way, using high-resolution near-infrared techniques. This work refines our previous analysis mainly by greatly improving the definition of the coordinate system, which reaches a long-term astrometric accuracy of ≈ 300 μas, and by investigating in detail the individual systematic error contributions. The combination of a long-time baseline and the excellent astrometric accuracy of adaptive optics data allows us to determine orbits of 28 stars, including the star S2, which has completed a full revolution since our monitoring began. Our main results are: all stellar orbits are fit extremely well by a single-point-mass potential to within the astrometric uncertainties, which are now ≈ 6× better than in previous studies. The central object mass is $(4.31 \pm 0.06|_{stat} \pm 0.36|_{R_0}) \times 10^6 M_\odot$, where the fractional statistical error of 1.5% is nearly independent from R_0, and the main uncertainty is due to the uncertainty in R_0. Our current best estimate for the distance to the Galactic center is $R_0 = 8.33 \pm 0.35$ kpc. The dominant errors in this value are systematic. The mass scales with distance as $(3.95 \pm 0.06) \times 10^6 (R_0/8\,\mathrm{kpc})^{2.19} M_\odot$. The orientations of orbital angular momenta for stars in the central arcsecond are random. We identify six of the stars with orbital solutions as late-type stars, and six early-type stars as members of the clockwise-rotating disk system, as was previously proposed. We constrain the extended dark mass enclosed between the pericenter and apocenter of S2 at less than 0.066, at the 99% confidence level, of the mass of Sgr A*. This is two orders of magnitudes larger than what one would expect from other theoretical and observational estimates.

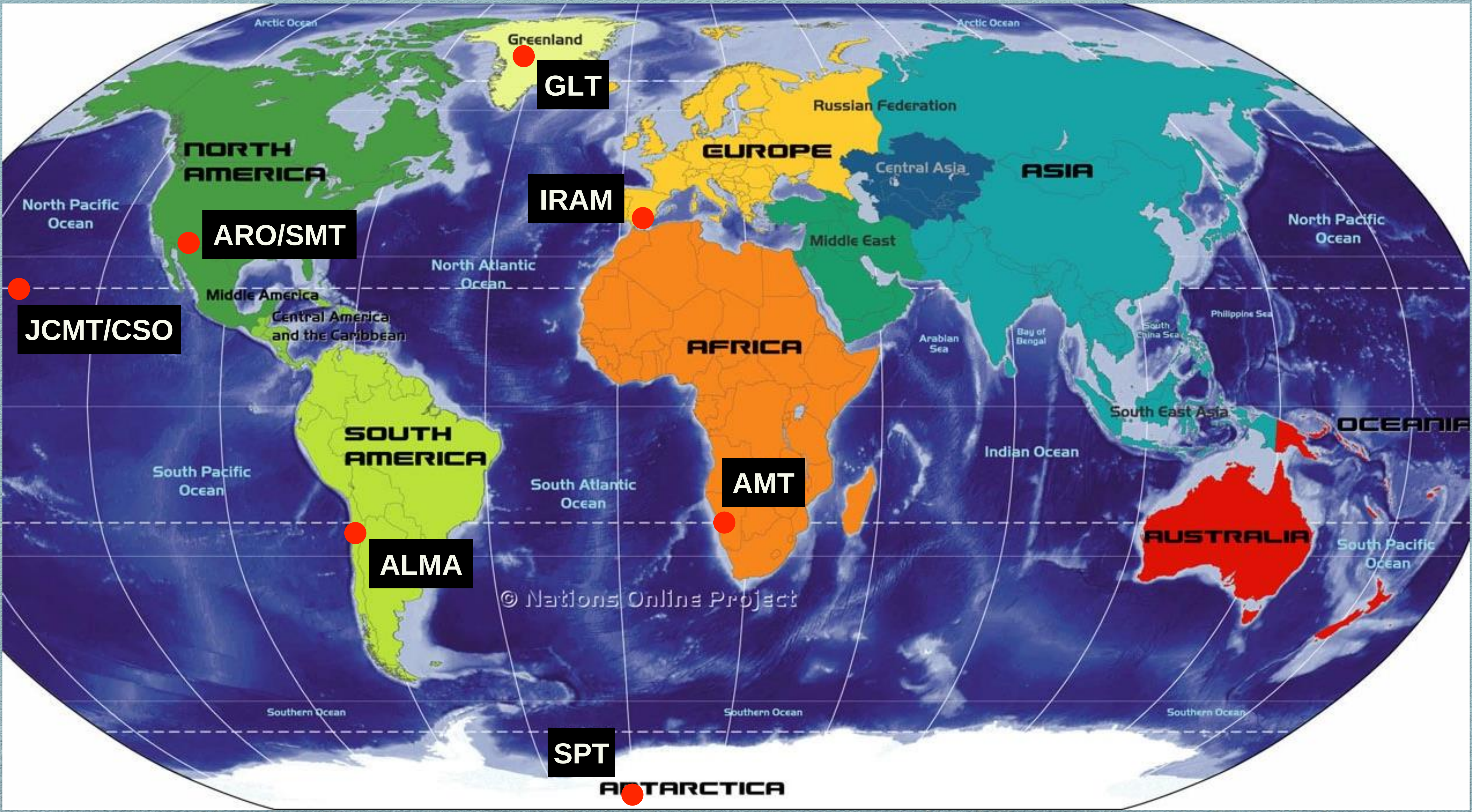
$$M \approx 4 \times 10^6 M_\odot$$

How large is the EH?

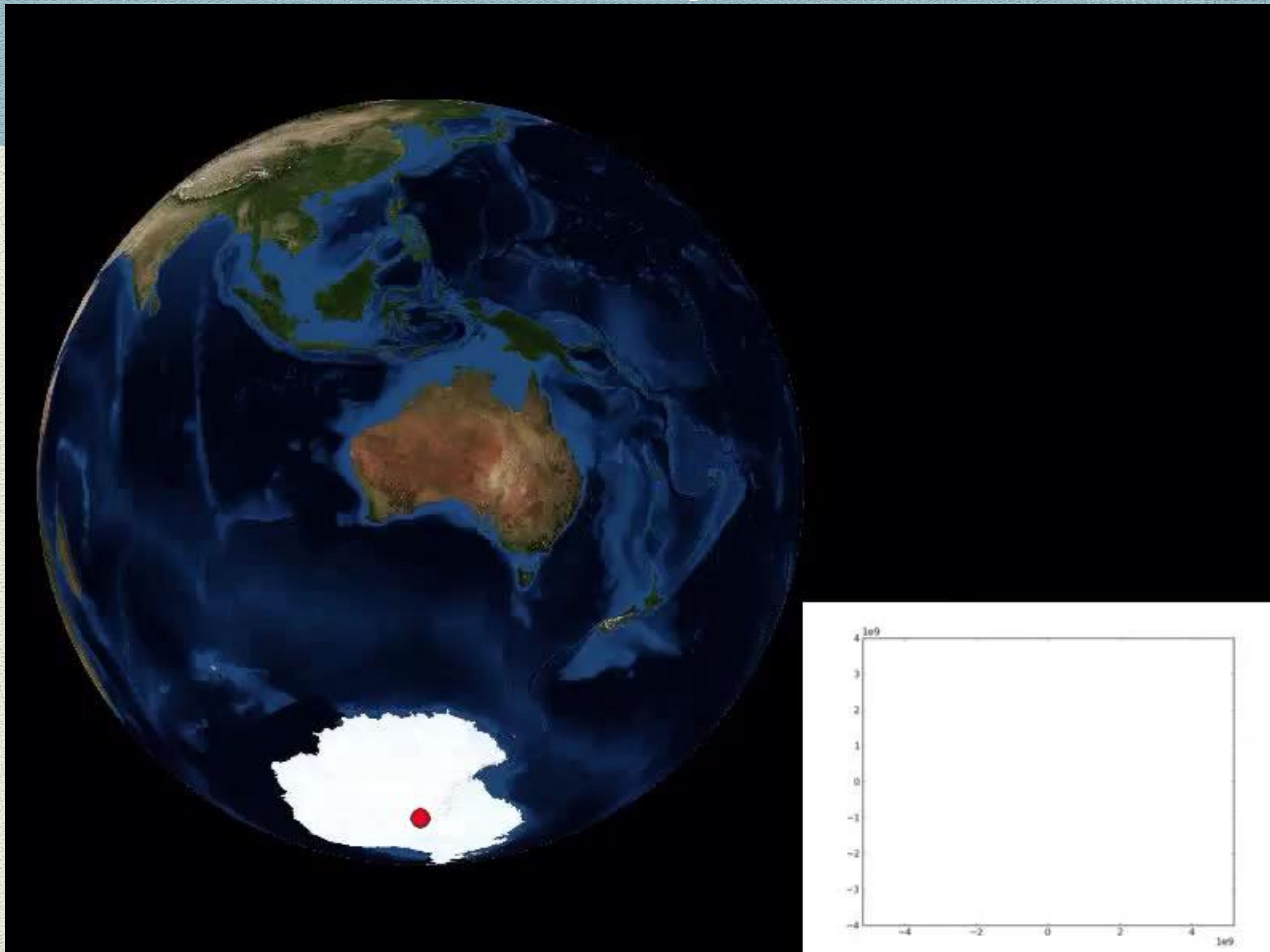
- We find $c = \sqrt{\frac{2GM}{R}} \rightarrow \boxed{R = 1.18 \times 10^{10} \text{ metres}}$
- We are 8kpc from the centre of the MW
- So, the size of the EH is 9.9 micro arc seconds
- Resolution (in radians) is given by $\theta = \frac{1.22\lambda}{D}$
  - At visible wavelengths, D~3.5km
  - At 21cm, D~1.33 million km
  - At 1mm, D~6,350 km
- Millimetre wavelengths are the only way to image the event horizon!



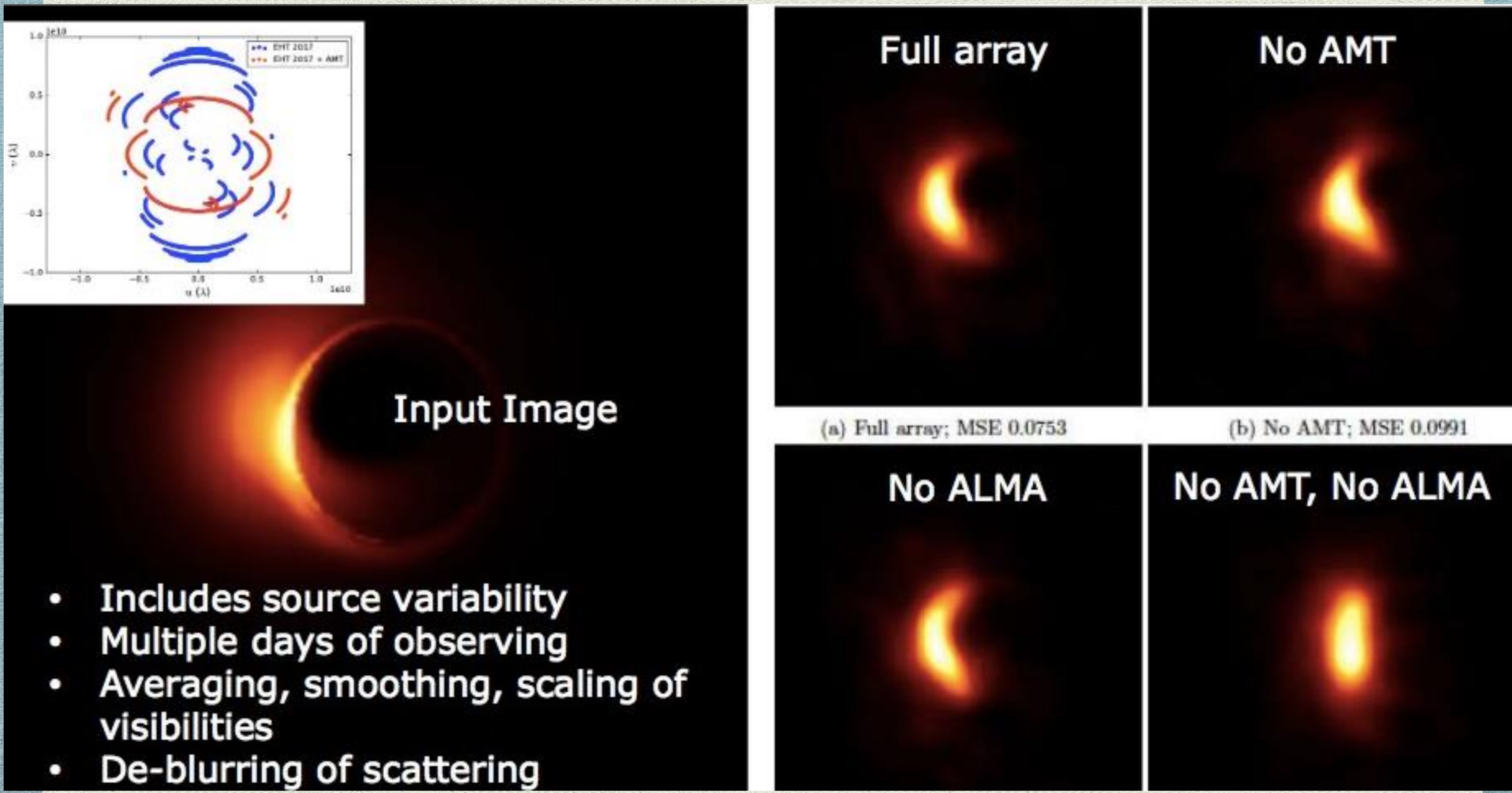
The Event Horizon Telescope



A mm telescope in Africa



AMT is a vital link



African mm-Wave Telescope

The Africa Millimetre Telescope

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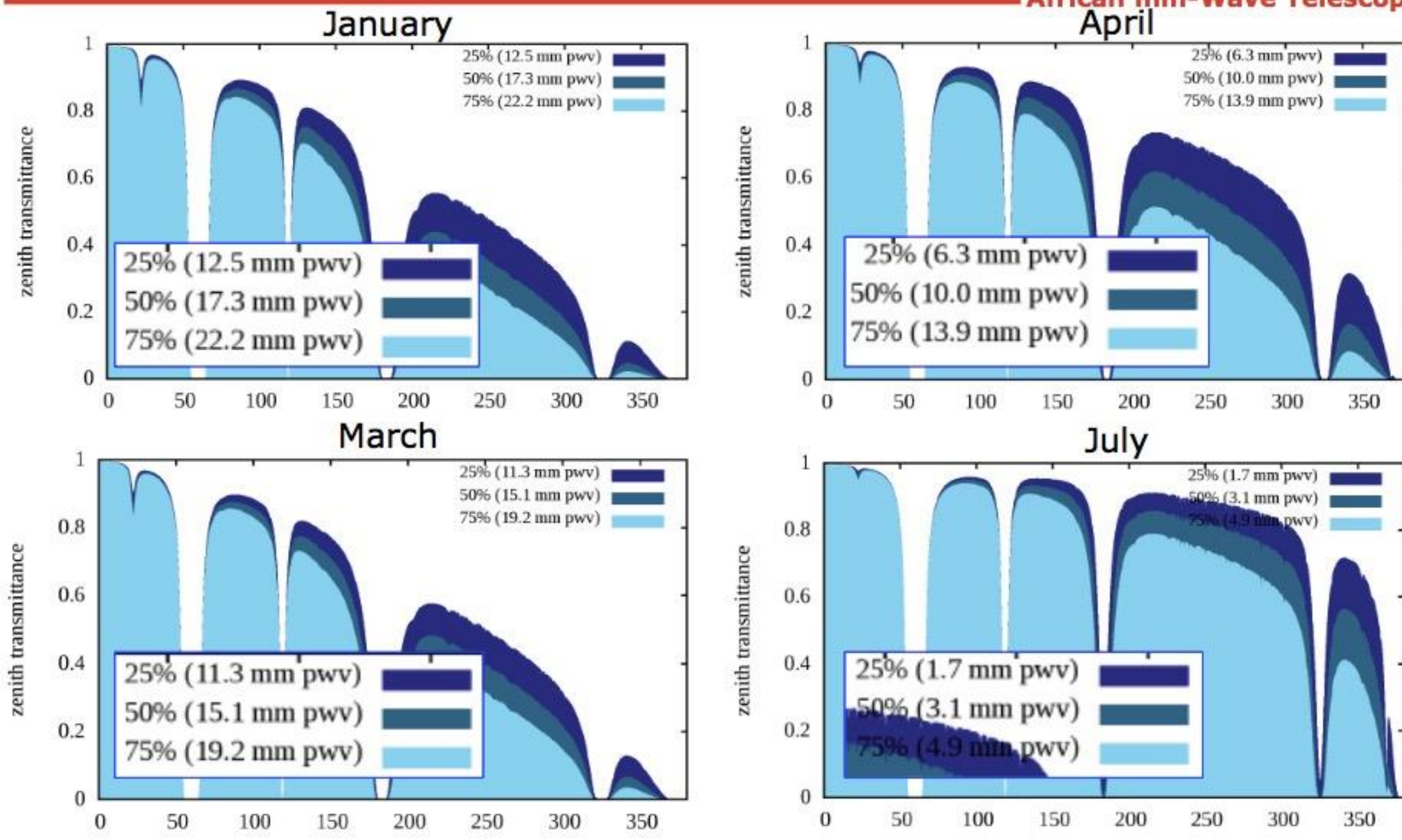
Preliminary site testing

Gamsberg – Annual Variation

x-axis = Frequency in GHz

1mm=300 GHz

African mm-Wave Telescope



H. Falcke, AMT, Slide Nr. 28

Conclusions

- The supermassive black hole at the centre of the Milky Way has an event horizon which subtends an angle of about 10 micro arc seconds
- The only wavelength which can currently be used to image such tiny angles is millimetre waves using VLBI
- Only dry places can do millimetre wave astronomy and there is currently no mm-wave telescope in Africa
- Mount Gamsberg in Namibia is the best site on the continent
- The Africa Millimetre Telescope will provide a vital link in the world-wide VLBI network to image the black hole's event horizon