Event Horizon Telescope

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Black Hole Initiative, Harvard University Smithsonian Astrophysical Observatory



Event Horizon Telescope





CTA Symposium, Bologna 9 May 2019

2009 decadal review white paper

Imaging an Event Horizon: submm-VLBI of a Super Massive Black Hole

A Science White Paper to the Decadal Review Committee

Authors:

Sheperd Doeleman (MIT Haystack Observatory) Eric Agol (U. Washington) Don Backer (UC Berkeley) Fred Baganoff (MIT) Geoffrey C. Bower (UC Berkeley) Avery Broderick (CITA) Andrew Fabian (U. Cambridge) Vincent Fish (MIT Haystack Observatory) Charles Gammie (U. Illinois Urbana-Champaign) Paul Ho (ASIAA) Mareki Honma (NAOJ) Thomas Krichbaum (MPIfR) Avi Loeb (Harvard-Smithsonian CfA) Dan Marrone (NRAO/U. Chicago) Mark Reid (Harvard-Smithsonian CfA) Alan Rogers (MIT Haystack Observatory) Irwin Shapiro (Harvard-Smithsonian CfA) Peter Strittmatter (U. Arizona Steward Observatory) Remo Tilanus (JCMT) Jonathan Weintroub (Harvard-Smithsonian CfA) Alan Whitney (MIT Haystack Observatory) Melvyn Wright (UC Berkeley) Lucy Ziurys (U. Arizona Steward Observatory)

2009 decadal review white paper

Imaging an Event Horizon: submm-VLBI of a Super Massive Black Hole

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Summary:

"Over the next decade, existing and planned mm/submm facilities can be combined into a high sensitivity, high angular resolution "Event Horizon Telescope", capable of imaging a black hole."











FRANKFURT AM MAIN





Max-Planck-Institut für Radioastronomie



Large Millimeter Telescope Alfonso Serrano



MIT HAYSTACK OBSERVATORY













Event Horizon Telescope: the Team



Nijmegen, Netherlands, November 2018

O over 200 scientists O contributors from 18 countries O over 60 institutions



Shadow imaging story



"It is conceptually interesting, if not astrophysically very important, to calculate the precise apparent shape of the black hole... Unfortunately, there seems to be no hope of observing this effect."

Bardeen 1973

Wikipedia



Shadow imaging story



Luminet 1978



Historia obrazów czarnej dziury



Luminet 1978

"Hence, there exists a realistic expectation of imaging the event horizon of a black hole within the next few years." Falcke+ 1999







Event Horizon Telescope

Historia obrazów czarnej dziury

Bronzwaer+ 2018



Very Long Baseline Interferometry







Very Long Baseline Interferometry







Very Long Baseline Interferometry





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- \Rightarrow M87 central black hole is really humongous







Event Horizon Telescope



EHT 2019. Paper II. Instrument





Images and mass of M87







Spin of M87

It is the **BH angular momentum**, not the **disk angular momentum** that determines the image orientation





Spin of M87

It is the **BH angular momentum**, not the **disk angular momentum** that determines the image orientation



BH spin-away (clockwise rotation) is strongly favored







Variability of M87: images





3C279 images





Sgr A* in 2017 data





Sgr A* in 2017 data





Other potentially interesting sources observed in 2017

- ☆ Centaurus A (1 night)
- ☆ 3C279 (4 nights)
- ☆ OJ287 (2 nights)
- ☆ J1924 (5 nights)
- ☆ 3C273 (1 night)



Multiwavelength campaign in 2017: M87



Event Horizon Telescope

Multiwavelength campaign in 2017: Sgr A*



Event Horizon Telescope

Upgrades for 2020s

- \therefore more stations (+2 in 2020)
- ☆ increased bandwidth (to 128 GBps)
- x some more medium length baselines (~100 km)
- ☆ technical upgrades at telescopes (LMT)
- \approx low orbit space VLBI for fast aperture synthesis
- \Rightarrow small custom built radio telescopes
- ☆ MEO/GEO orbiter to increase the resolution



Astro2020 Science White Paper

Black Hole Physics on Horizon Scales

Thematic Areas:

Cosmology and Fundamental Physics, Formation and Evolution of Compact Objects, Galaxy Evolution, Multi-Messenger Astronomy and Astrophysics

Principal Author:

Name: Sheperd S. Doeleman, EHT Director Institution: Center for Astrophysics | Harvard and Smithsonian Email: sdoeleman@cfa.harvard.edu

Co-authors:

Kazunori Akiyama^{1,2,3}, Lindy Blackburn⁴, Katherine L. Bouman⁴, Geoffrey C. Bower⁵, Avery E. Broderick⁶, Andrew Chael^{4,7}, Vincent L. Fish², Michael D. Johnson^{4,7}, Thomas P. Krichbaum⁸, Colin J. Lonsdale², Daniel Palumbo^{4,7}, Dominic W. Pesce^{4,7}, Alexander W. Raymond^{4,7}, Jonathan Weintroub⁴, Maciek Wielgus^{4,7}

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Name: Sheperd S. Doeleman, EHT Director Institution: Center for Astrophysics | Harvard and Smithsonian Email: sdoeleman@cfa.harvard.edu

"Over the coming year, the first EHT results will clarify the state of the art in black hole imaging on horizon scales, bringing into focus the full science potential of this new field. Expected enhancements to the EHT would enable time-resolved videos of black hole jet launching and accretion, with potential significant expansion of black hole physics in Sgr A*, M87 and other sources that require high angular resolution."