Lecture 18

Taking a picture of a black hole: computational imaging taken to an extreme
The black hole story, told in the style of *Rosencrantz and Guildenstern are Dead*

Many slides courtesy of Event Horizon Telescope Imaging Working Group, and Katie Bouman
POLONIUS: My Lord! I have news to tell you.

HAMLET (releasing ROS and mimicking): My lord, I have news to tell you... When Roscius was an actor in Rome...

(ROS comes down to re-join GUIL.)

POLONIUS (as he follows HAMLET out): The actors are come hither my lord.

HAMLET: Buzz, buzz.

(Exeunt HAMLET and POLONIUS.)

(ROS and GUIL ponder. Each reluctant to speak first.)

GUIL: Hm?

ROS: Yes?

GUIL: What?

ROS: I thought you...

GUIL: No.

ROS: Ah.

(Pause.)

GUIL: I think we can say we made some headway.

ROS: You think so?

GUIL: I think we can say that.

ROS: I think we can say he made us look ridiculous.

GUIL: We played it close to the chest of course.

ROS (derisively): "Question and answer. Old ways are the best ways"! He was scoring off us all down the line.

GUIL: He caught us on the wrong foot once or twice, perhaps, but I thought we gained some ground.

ROS (simply): He murdered us.

GUIL: He might have had the edge.

ROS (roused): Twenty-seven - three, and you think he might have had the edge?! He murdered us.
MIT’s Haystack Observatory, Westborough, MA
Dear Bill, Dan and Katie,

It was great to talk with you all and to hear about Dan and Katie's interesting work - I don't think I'll look at leaves or fabric in the same way again.

Your ideas and gameplan sound reasonable, and is along the lines I was hoping for - a fresh look at this problem with unjaded astronomer eyes. There will undoubtedly be course corrections along the way, but this is a good start. We can generate fourier plane baseline tracks for you, or we can supply routines that will do that for you (functions of telescope location on the Earth, Greenwich mean time, and the sky position of the source).

I wonder to what extent the textured approach will contain the imprint of the types of images we expect to see (a 'gentle' prior), but let's see what happens. I really like the idea of generating a family of images that all obey the observations, but differ where we have no fourier data.

All the Best, Shep

In the shadow of a black hole
1:13 - 3:50 or 5:05.
Hubble Telescope
(optical wavelength)

NASA, ESA and the Hubble Heritage Team (STScI/AURA); Acknowledgment: P. Cote (Institute of Astrophysics) and E. Baltz (Stanford University) Herzberg
This artist’s impression depicts the black hole at the heart of the enormous elliptical galaxy Messier 87 (M87). This black hole was chosen as the object of paradigm-shifting observations by the Event Horizon Telescope. The superheated material surrounding the black hole is shown, as is the relativistic jet launched by M87’s black hole.

Credit: ESO/M. Kornmesser
Black Hole Simulation
The Fourier Transform relationship between the light amplitudes entering the aperture of the telescope and those focussed at the sensor impose a resolution limit on the image from an optical system.

\[ \theta = 1.22 \frac{\lambda}{D} \]

measured wavelength

\[ \frac{1.3 \text{mm}}{12.7 \times 10^6 \text{m}} = 25.7 \mu \text{arc seconds} \]

diameter of Earth

black hole photon capture radius:

\[ R_c = \frac{\sqrt{27GM}}{c^2} \]

Predicted black hole mass: 3-6 Billion solar masses, 55M light years away implying shadow size: between 42 and 20 micro arc seconds

https://www.researchgate.net/figure/A-picture-of-a-Comb-s-rect-s-sinc-s-Gaussian-m-s_fig1_307862015
How Big Must Our Telescope Be?

- **Telescope Size**: 13 million meters
- **Wavelength**: 1.3 mm
- **Angular Resolution**: 20 μas

Simulation of M87

Ideal Image with Earth-Sized Telescope
Figure 2: The same baseline as in Figure 1, but for waves incident from an angle $\theta$ from the vertical. The waves arrive at the antennas again exactly in phase, because the angle is such that the difference in path length is $\lambda$. 
We run a double-slit interference experiment in reverse” —Shep Doleman

Double Slit Interference

Assumption of infinite source distance gives plane wave at slit so that all amplitude elements are in phase.

\[
\tan \theta = \frac{y}{D}
\]

For distant screen assumption

\[
\tan \theta \approx \sin \theta \approx \theta \approx \frac{y}{D}
\]

\[d \sin \theta = m\lambda\]

\[y \approx \frac{m\lambda D}{d}\]
The theorem states that, for ideal sensors, the time-averaged correlation of the measured signals from two telescopes, $i$ and $j$, for a single wavelength, $\lambda$, can be approximated as:

$$\Gamma_{i,j}(u,v) \approx \int_{\ell} \int_{m} e^{-i2\pi(u\ell+vm)} I_\lambda(\ell,m) d\ell dm \quad (1)$$

where $I_\lambda(\ell,m)$ is the emission of wavelength $\lambda$ traveling from the direction $\hat{s} = (\ell, m, \sqrt{1 - \ell^2 - m^2})$. The dimensionless coordinates $(u,v)$ (measured in wavelengths) are the projected baseline, $B$, orthogonal to the line of sight.\textsuperscript{1}
The Event Horizon Telescope (EHT)

Very Long Baseline Interferometry
Imaging a Black Hole with the Event Horizon Telescope

EHT Collaboration
FOURIER DOMAIN COVERAGE OF THE 4 NIGHTS OF OBSERVATIONS

Fourier domain

Because the image is real valued, the Fourier transform is Hermitian. K telescopes gives K chose 2 baselines, or observed Fourier frequencies. As the Earth rotates over a night, the projected baselines sweep out elliptical paths in Fourier space.
ICCV 2015 was in Santiago, Chile

Shep said we should go see the Alma radio telescopes in Atacama, and I arranged for a trip there, with Bernhard Scholkopf, Yoav Schechner, and Katie Bouman.

Timelapse videos from Bernhard, from Atacama, 2015


https://youtu.be/8YOqdAooO9A
The Atacama Large Millimeter/submillimeter Array (ALMA) by night, u...

ESO Observatory
MAR 2013
Dec. 12, 2015
Below ALMA telescope array, Atacama, Chile 9,000 feet
Yoav in pressurized car, going to 15,000 feet
ALMA telescope array, 15,000 feet. Atacama, Chile, 2015
ALMA telescope array, 15,000 feet. Atacama, Chile, 2015
Very Long Baseline Interferometry (VLBI)
The Computational Imaging Problem

True Image

Reconstruction

ALGORITHM

Sparse Measurements
The Computational Imaging Problem

True Image

Inverse Fourier Transform

Sparse Measurements

Reconstruction
Inverting the Imaging System: Ambiguity

True Image ➔ Inverse Fourier Transform ➔ Sparse Measurements

Reconstruction

Question mark
Figure 10:  
(a) An example (model) sky map. 
(b) The corresponding visibilities (Fourier Transform of the map). 
(c) The synthesized beam, or point-spread-function, of a model antenna array. 
(d) The sampling function of the array, whose Fourier Transform gives the beam in (b). 
(e) The product of panels (d) and (c), representing the sampled visibilities. These are the actual measurements from the array. 
(f) The dirty map that results from the Fourier Transform of the sampled visibilities. This is the same as the convolution of the map in (c) and the synthesized beam in (b).
Katie presenting EHT poster at CVPR 2016
Some of the image priors explored for Event Horizon Telescope black hole image reconstructions one has ever seen

(what assumptions do you make about an image of something that no one has ever seen before?)

• Positivity: the light intensity must be positive.
• Compactness: The source has a finite size
• Image entropy
• Image smoothness
• Image sparsity in the pixel, or gradient, domains
VLBI Reconstruction Dataset

A Dataset Designed to Train and Test Very Long Baseline Interferometry Image Reconstruction Algorithms

EHT Imaging Challenge

Welcome to the Event Horizon Telescope Imaging Challenge Webpage! This challenge is meant to help us understand the performance of different imaging algorithms on future Event Horizon Telescope (EHT) data. We hope the results of the challenge will help us better understand the biases of each imaging algorithm, and aid in developing better methods.

Next Deadline: December 20, 2017

- Testing Data and Submission Instructions
- Data Parameters and Noise Properties
- Sample Data With Ground Truth Images
- Park Challenges
- Data Formats and Conversion
- Sample Imaging Script
- Questions and Feedback

Testing Data and Submission Instructions

1. Download the test data from HERE.

2. Use your algorithm to generate an image for each of the data files. For each <filename>.txt file, submit a FITS image with the name <filename>.fits and the FOV specified in the README file. Further instructions can be found in the README file.

3. Submit your reconstructed Images. Compress all of your reconstructed FITS images into a ZIP file. Submit this ZIP file with the required additional information.

Method Name: [Input Field]
Email: [Input Field]
Images: [File Upload]

Additional Information (such as website/code links): [Input Area]
Sample Data With Ground Truth Images

We provide a set of sample data, along with their ground truth images, to help in getting your imaging algorithms working on the blind, test data.

### Static Emission

You can download the sample data from [here](#). This sample data was generated with the same telescope parameters as the blind, test data. We have included data without any systematic errors or atmospheric errors, data with just atmospheric errors, and data with both systematic and atmospheric errors. Their naming is as follows:

<table>
<thead>
<tr>
<th>Filename</th>
<th>Property</th>
</tr>
</thead>
<tbody>
<tr>
<td>challenge_x_wNoPhaseError</td>
<td>Only thermal noise included in visibility measurements</td>
</tr>
<tr>
<td>challenge_x</td>
<td>Thermal and phase (atmospheric) errors included in visibility measurements</td>
</tr>
<tr>
<td>challenge_x_wSystematics</td>
<td>Thermal, amplitude (systematic) and phase (atmospheric) errors included</td>
</tr>
</tbody>
</table>

#### Sample Ground Truth Images

![Sample Ground Truth Images](#)

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>Source Location</th>
<th>Telescopes</th>
<th>Total Flux (Janskys)</th>
<th>Field of View (arcseconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SgrA*</td>
<td>ALMA, SMT, LMT, SMA, SPT, CARMA, PV, PdBI, KP, Haystack</td>
<td>2</td>
<td>0.00016</td>
</tr>
<tr>
<td>2</td>
<td>SgrA*</td>
<td>ALMA, SMT, LMT, SMA, SPT, CARMA, PV, PdBI, KP, Haystack</td>
<td>2</td>
<td>0.00025</td>
</tr>
<tr>
<td>3</td>
<td>SgrA*</td>
<td>ALMA, SMT, LMT, SMA, FV, SPT, KP, PdBI</td>
<td>2</td>
<td>0.00016</td>
</tr>
<tr>
<td>4</td>
<td>SgrA*</td>
<td>ALMA, SMT, LMT, SMA, FV, SPT</td>
<td>2</td>
<td>0.00016</td>
</tr>
<tr>
<td>5</td>
<td>M87</td>
<td>ALMA, SMT, LMT, SMA, SPT, CARMA, PV, PdBI, KP, Haystack</td>
<td>2</td>
<td>0.00010</td>
</tr>
<tr>
<td>6</td>
<td>M87</td>
<td>ALMA, SMT, LMT, SMA, SPT, CARMA, PV, PdBI, KP, Haystack</td>
<td>2</td>
<td>0.00010</td>
</tr>
<tr>
<td>7</td>
<td>M87</td>
<td>ALMA, SMT, LMT, SMA, FV, SPT, KP, PdBI</td>
<td>2</td>
<td>0.00025</td>
</tr>
<tr>
<td>8</td>
<td>M87</td>
<td>ALMA, SMT, LMT, SMA, FV</td>
<td>2</td>
<td>0.00010</td>
</tr>
</tbody>
</table>
Extreme Imaging via Physical Model Inversion: Seeing Around Corners and Imaging Black Holes

by

Katherine L. Bouman

B.S.E., Electrical Engineering, University of Michigan, 2011
S.M., Electrical Engineering and Computer Science, M.I.T., 2013

Submitted to the Department of Electrical Engineering and Computer Science
in partial fulfillment of the requirements for the degree of

Doctor of Philosophy
in Electrical Engineering and Computer Science
at the Massachusetts Institute of Technology

September 2017

© 2017 Massachusetts Institute of Technology
All Rights Reserved.

Signature of Author: ___________________________________________

Department of Electrical Engineering and Computer Science
August 31, 2017

Certified by: __________________________________________

Professor William T. Freeman
Thomas and Gerd Perkins Professor of Electrical Engineering and Computer Science
Thesis Supervisor
All sites were technically ready and with good weather on the first night of the observing window. Observations were triggered on 2017 April 5, 6, 7, 10, and 11. Table 1 shows the median zenith sky opacities for each of the triggered days. April 8 was not triggered due to thunderstorms at the LMT, SMT shutdown due to strong winds, and the need to run technical tests at ALMA. April 9 was not triggered due to a chance of the SMT remaining closed due to strong winds and LMT snow forecast. Weather was good to excellent for all other stations throughout the observing window.

…

Observations from the EHT’s 2017 April campaign are the first ever to have the necessary sensitivity, coverage, and resolution for horizon-scale imaging of black hole candidates M87 and SgrA*.
2nd way the EHT got lucky

For M87, the expected shadow diameter is 19–38\(\mu\)as.

... 

We present the first Event Horizon Telescope (EHT) images of
M87, using observations from April 2017 at 1.3 mm
wavelength. These images show a prominent ring with a
diameter of \(\sim 40 \mu\)as,
The black hole’s light arrives at the telescopes and is digitized as two-bit data streams. Petabytes of raw data are saved onto hundreds of hard disks.

The correlator is a special-purpose supercomputer that combines data from the telescopes, to recover measurements that would be seen from an Earth-size telescope.

Calibration algorithms find the weak signals hiding in the correlator output, and more precisely tune the data to extract a stronger signal.

Extrating the Black Hole’s Weak Signal

350 Tbytes / day of data…

Correlating all the data, processing checking, writing, took 2 years!
The Event Horizon Telescope
The Event Horizon Telescope
Lo-band eht-imaging on April 11: slowly building up data
Team 1 – End of the First Day of Imaging M87

(mention my contribution)
EHT Imaging Working Group
The dangers of false confidence and collective confirmation bias are magnified for the EHT because the array has fewer sites than typical VLBI arrays, there are no previous VLBI images of any source at 1.3 mm wavelength, and there are no comparable black hole images on event-horizon scales at any wavelength.

We subdivided our first M87 imaging efforts into four separate imaging teams. The teams were blind to each others' work, prohibited from discussing their imaging results and even from discussing aspects of the data that might influence imaging (e.g., which stations or data might be of poor quality).
The Imaging WG was divided into four independent teams:

- **Team 1**: The Americas (SAO, UoA, U.Concepcion)
- **Team 2**: Global (MIT Haystack, Radboud U, NAOJ)
- **Team 3**: Cross-Atlantic (MPIfR, Boston U, IAA, Aalto)
- **Team 4**: East Asia (ASIAA, KASI, NAOJ)

Each team blindly reconstructed images. 

**Goal**: Assess human bias.
The First EHT Images of M87
July 24, 2018

Each team blindly reconstructed images
Goal: Assess human bias
Figure 4. The first EHT images of M87, blindly reconstructed by four independent imaging teams using an early, engineering release of data from the April 11 observations. These images all used a single polarization (LCP) rather than Stokes $I$, which is used in the remainder of this Letter. Images from Teams 1 and 2 used RML methods (no restoring beam); images from Teams 3 and 4 used CLEAN (restored with a circular 20 $\mu$as beam, shown in the lower right). The images all show similar morphology, although the reconstructions show significant differences in brightness temperature because of different assumptions regarding the total compact flux density (see Table 2) and because restoring beams are applied only to CLEAN images.
The Event Horizon Telescope

The First EHT Images of M87
July 24, 2018

The Event Horizon Telescope

2nd EHT Imaging Workshop
Imaging Stage 2/2: Imaging Parameter Survey

Imaging algorithms were tested on a suite of synthetic datasets.

**Goal:** Optimize imaging algorithms with objective performance assessment.
Imaging Stage 2/2: Imaging Parameter Survey
Figure 7. Selection of the eht-imaging (RML) parameter survey results on real and synthetic data with April 11 EHT baseline coverage. A 2D slice of the 7D parameter space is displayed, corresponding to different weights on the MEM and TV regularizers. All other parameters are kept constant (Compact Flux = 0.6 Jy, Initial/MEM FWHM = 40 μas, Systematic Error = 1%, TSV = 0, and ℓ₁ = 0). The left panel shows results of the parameter search on the Crescent synthetic data, while the right panel shows reconstructions for the same parameters on M87 data. Images that meet the threshold for the Top Set are outlined in green. Note that the upper-left reconstruction has no regularization; it is produced by enforcing only image positivity and a constrained FOV.
Figure 10. Cross-validation of the imaging parameter selection procedure. In each of the left four columns, we show reconstructed images for the simple geometric source models. These reconstructions do not use the fiducial imaging parameters identified by the full training set; instead, we selected the imaging parameters for each geometric source model after excluding that particular model from the parameter selection process. For example, in the disk reconstructions, the parameters were selected by assessing reconstructions of only the ring, crescent, and double source models. Thus, the selected parameters vary among these four columns, but we can verify that the training sets do not overly constrain the outcomes. In the fifth column, we show reconstructions of a GRMHD snapshot (Paper V) using the fiducial M87 parameters selected from all four geometric models. That is, the script and parameters used to produce these GRMHD image reconstructions are identical to those used to produce our fiducial M87 images (shown in Figure 11). Because the GRMHD snapshot has a substantially higher peak brightness than the reconstructions, its column has been scaled to the peak brightness of the eht-imaging reconstruction.
Fiducial images for all four days and three scripts

- Best images out of 1008, 37500, and 10800 images surveyed by the Difmap, eht-library, and SMILI scripts, respectively
- All images from the four different observing days show the asymmetric ring structure corresponding to the black hole shadow
Fiducial images of M87 for April 11 restored to an equivalent resolution show remarkably similar structure.
Comparison of reconstructions, in the Fourier domain
Focus on the First Event Horizon Telescope Results

Shep Doeleman (EHT Director) on behalf of the EHT Collaboration

April 2019

Figure 1. EHT images of M87 on four different observing nights. In each panel, the white circle shows the resolution of the EHT. All four images are dominated by a bright ring with enhanced emission in the south. From Paper IV (Figure 15).

We report the first image of a black hole.

This Focus issue shows ultra-high angular resolution images of radio emission from the supermassive black hole believed to lie at the heart of galaxy M87 (Figure 1). A defining feature of the images is an irregular but clear bright ring, whose size and shape agree closely with the expected lensed photon orbit of a 6.6 billion solar mass black hole. Soon after Einstein introduced general relativity, theorists derived the full analytic form of the photon orbit, and first simulated its lensed appearance in the 1970s. By the 2000s, it was possible to sketch the “shadow” formed in the image when synchrotron emission from an optically thin accretion flow is lensed in the black hole’s gravity. During this time, observational evidence began to build for the existence of black holes at the centers of active galaxies, and in our own Milky Way. In particular, a steady progression in radio astronomy enabled very long baseline interferometry (VLBI) observations at even-shorter wavelengths, targeting supermassive black holes with the largest apparent event horizons: M87, and Sgr A* in the Galactic Center. The compact sizes of these two sources were confirmed by studies at 1.3mm, first exploiting baselines that ran from Hawai‘i to the mainland US, then with increased resolution on baselines to Spain and Chile.
The sequence of Letters in this issue provides the full scope of the project and the conclusions drawn to date. Paper II opens with a description of the EHT array, the technical developments that enabled precursor detections, and the full range of observations reported here. Through the deployment of novel instrumentation at existing facilities, the collaboration created a new telescope with unique capabilities for black hole imaging. Paper III details the observations, data processing, calibration algorithms, and rigorous validation protocols for the final data products used for analysis. Paper IV gives the full process and approach to image reconstruction. The final images emerged after a rigorous evaluation of traditional imaging algorithms and new techniques tailored to the EHT instrument—alongside many months of testing the imaging algorithms through the analysis of synthetic data sets. Paper V uses newly assembled libraries of general relativistic magnetohydrodynamic (GRMHD) simulations and advanced ray-tracing to analyze the images and data in the context of black hole accretion and jet-launching. Paper VI employs model fits, comparison of simulations to data, and feature extraction from images to derive formal estimates of the lensed emission ring size and shape, black hole mass, and constraints on the nature of the black hole and the space-time surrounding it. Paper I is a concise summary.
Our image of the shadow confines the mass of M87 to within its photon orbit, providing the strongest case for the existence of supermassive black holes. These observations are consistent with Doppler brightening of relativistically moving plasma close to the black hole lensed around the photon orbit. They strengthen the fundamental connection between active galactic nuclei and central engines powered by accreting black holes through an entirely new approach. In the coming years, the EHT Collaboration will extend efforts to include full polarimetry, mapping of magnetic fields on horizon scales, investigations of time variability, and increased resolution through shorter wavelength observations.

In short, this work signals the development of a new field of research in astronomy and physics as we zero in on precision images of black holes on horizon scales. The prospects for sharpening our focus even further are excellent.

First M87 Event Horizon Telescope Results. I. The Shadow of the Supermassive Black Hole
The Event Horizon Telescope Collaboration et al. 2019 ApJL 875 L1

First M87 Event Horizon Telescope Results. II. Array and Instrumentation

First M87 Event Horizon Telescope Results. III. Data Processing and Calibration

First M87 Event Horizon Telescope Results. IV. Imaging the Central Supermassive Black Hole
The Event Horizon Telescope Collaboration et al. 2019 ApJL 875 L4

First M87 Event Horizon Telescope Results. V. Physical Origin of the Asymmetric Ring

First M87 Event Horizon Telescope Results. VI. The Shadow and Mass of the Central Black Hole
First M87 Event Horizon Telescope Results. I. The Shadow of the Supermassive Black Hole

My friend, Carl

“No, it won’t be on the front page of every newspaper because the image is just too blurry”
One less mystery in our vast universe

Earthbound teams record first image of black hole

By Brian MacQuarrie
GLOBE STAFF

Katherine Bouman had devoted years to the astonishing quest — to help capture the first image of a massive black hole in a distant galaxy, a void so dense no light can escape.

But when the mind-bending breakthrough finally came almost a year ago, the discovery had to stay a secret.

So, after the stunning image was revealed to the world Wednesday, Bouman's excitement spilled out at what seemed the speed of light.

"We've been bursting at the seams about what we've seen, but we had to keep our mouths shut," said Bouman, 29, a doctoral graduate of MIT who continued her studies at the Harvard-Smithsonian Center for Astrophysics.

What she and a large team of scientists from MIT, Harvard, and other universities had seen was the first-ever image of a cosmic black hole 25 million light-years away, a time-warping and light-twisting mystery of the universe whose existence Albert Einstein had hinted at a century ago.

The image of a black hole spawned celebrations.

Middle of the pack total cases concerns about forgoing big donors
Watching in disbelief as the first image ever made of a black hole was in the process of being reconstructed.
3 years ago MIT grad student Katie Bouman led the creation of a new algorithm to produce the first-ever image of a black hole.

Today, that image was released.


2016 story: bit.ly/BlackHoleCSAIL

#EHTblackhole #EventHorizonTelescope
Here's the moment when the first black hole image was processed, from the eyes of researcher Katie Bouman. #EHTBlackHole #BlackHoleDay #BlackHole (w/@dfbarajas)
Take your rightful seat in history, Dr. Bouman! 🧟‍♀️

Congratulations and thank you for your enormous contribution to the advancements of science and mankind.

Here’s to #WomenInSTEM!
Congratulations to Dr. Katie Bouman, who developed the algorithm which captured the first ever image of a black hole! You are an inspiration to all Americans and especially to young women and girls with STEAM dreams!

cnn.com/2019/04/10/us/

That image of a black hole you saw everywhere...
The effort wouldn't have succeeded without Katie Bouman, who developed a crucial algorithm and

cnn.com

Congratulations Katie Bouman on this remarkable accomplishment! Thank you for leading by example and encouraging girls to push the boundaries of science. 🌟
#YouCanBeAnything #MoreRoleModels

This is Dr. Katie Bouman. She's the computer scientist behind the first-ever image of a black hole.

She developed the algorithm that turned telescopic data into the historic photo we see today.

550 6:46 PM - Apr 10, 2019

150 people are talking about this

Read more:
We at @MIT_CSAIL are so proud of the role our alum Dr. Katie Bouman played in the development of the first-ever picture of a black hole. She's been psyched about all the #blackhole interest & just wanted to clarify a few things. (1/7)

11:49 AM - 12 Apr 2019

128 Retweets 434 Likes

MIT CSAIL @MIT_CSAIL · Apr 12
In our first tweet about this, we linked to a 2016 story about an algorithm she led the development of while at CSAIL. That algorithm was intended to take a picture of a black hole, but didn't create the final image. (cont.)(2/7)

4 Retweets 81 Likes

MIT CSAIL @MIT_CSAIL · Apr 12
It inspired image validation procedures in the final paper, and the EHT team together developed new methods that were used in reconstructing the black hole image. (3/7)

2 Retweets 70 Likes
How Katie Bouman Accidentally Became the Face of the Black Hole Project

By Sarah Mervosh

April 11, 2019

Leer en español

As the first-ever picture of a black hole was unveiled this week, another image began making its way around the internet: a photo of a young scientist, clasping her hands over her face and reacting with glee to an image of an orange ring of light, circling a deep, dark abyss.

It was a photo too good not to share. The scientist, Katie Bouman, a postdoctoral fellow who contributed to the project, became an instant hero for women and girls in STEM, a welcome symbol in a world hungry for representation.

Public figures from Washington to Hollywood learned her name. And some advocates, familiar with how history can
I'm so excited that we finally get to share what we have been working on for the past year! The image shown today is the combination of images produced by multiple methods. No one algorithm or person made this image, it required the amazing talent of a team of scientists from around the globe and years of hard work to develop the instrument, data processing, imaging methods, and analysis techniques that were necessary to pull off this seemingly impossible feat. It has been truly an honor, and I am so lucky to have had the opportunity to work with you all.
Katie speaking at MIT
Katie speaking at MIT
Katie speaking at Stanford
Katie’s audience at Stanford
Katie speaking at CSAIL’s annual gala at ICA, April 27, 2019
Franny, Bill, Katie, Joe at ICA
next up: SgrA*

• The EHT team is processing the data from the black hole at the center of our galaxy
• Much less massive (4M vs 6.5B solar masses), and therefore faster dynamics than M87*
• They’re working on processing the SgrA* data now…