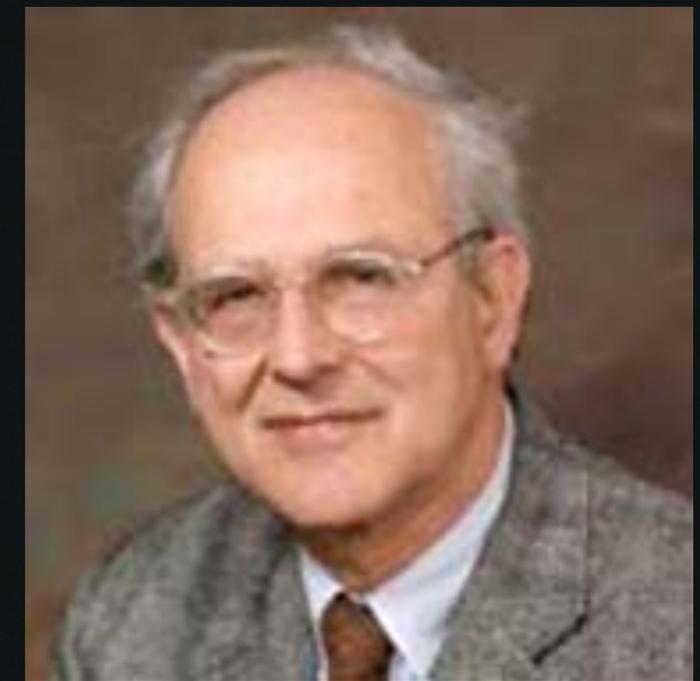
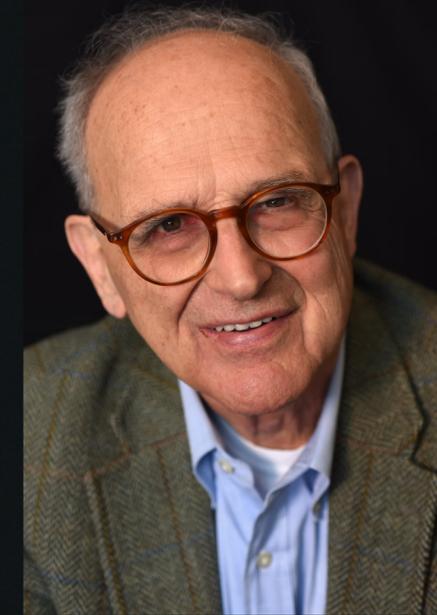


Listening to the Universe

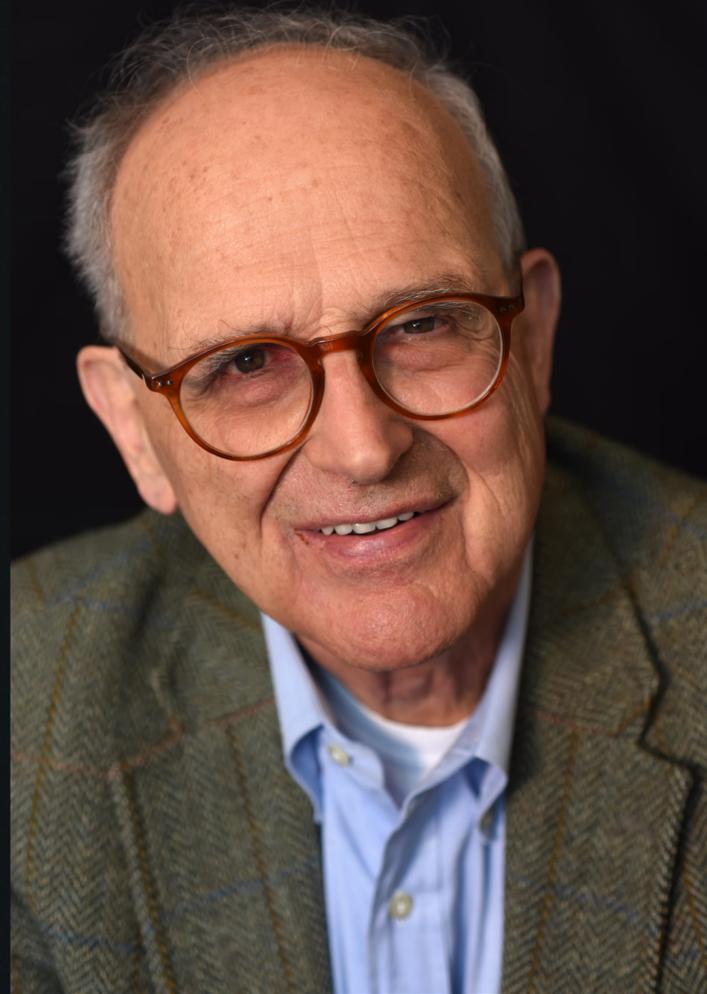
Vicky Kalogera 2/27/2026 Rai Weiss Symposium, MIT, Cambridge, MA



Listening Carefully:

What I learned from Rai Weiss

1999: listening to Rai for the first time



1999: First LIGO Collaboration Meeting at Livingston

LIGO SCIENTIFIC COLLABORATION

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
DEPARTMENT OF PHYSICS
BUILDING 20B-145
CAMBRIDGE, MASSACHUSETTS 02139

April 21, 1998

• Research and Development Groups

- ›› Stochastic Forces - Isolation systems and suspension
— David Shoemaker
- ›› Sensing Noise - lasers and optics
— Eric Gustafson
- ›› Interferometer Configurations
— Ken Strain

• Data Analysis Groups

- ›› Astrophysical Source Identification and Signatures
— Bruce Allen/Tom Prince
- ›› Detector Characterization
— William Hamilton/Daniel Sigg
- ›› Detection Confidence and Statistical Analysis
— Sam Finn/Albert Lazzarini

TO: Leaders of the Gravitational Wave Projects

I would like you to consider a strategy for the opening days of the large baseline interferometer gravitational wave detectors that will provide the best for the science itself and can be held up as a model for how a new field is opened responsibly.

The proposed strategy is extremely simple.

A detection of gravitational waves is to be announced only after a statistically meaningful analysis has been performed of the data of ALL instruments that were observing throughout the world.

The instruments include the large and medium baseline interferometers, the acoustic detectors and the prototype detectors.

The data analysis for the individual instruments is carried out by the scientists associated with these instruments and their collaborators. The data and statistical results are brought to a council composed of representatives from each observing group. The initial publication is submitted in two parts. A paper from the group(s) making the observation and their analysis and a second paper from the council discussing the statistical significance in regards to the worldwide effort, in particular, the probability and confidence of detection in some of the instruments as well as the reasons for non-detection in others.

Suggest that the council be formed within the next year and that one of the functions of the council be to maintain an inventory of the schedule of operations of the various gravitational wave detectors throughout the world.

Sincerely yours,

Rainer Weiss
Professor of Physics
MIT

Detection of Gravitational Waves

LIGO interferometers
(ies) to the limit of the statistics
to the limit of the statistics
between LA and WA
4 km

environmental monitor channels

ancillary detector channels

(ration)

LIGO interferometers
frequency and amplitude modulation indices
)

environmental monitor channels

ancillary detector channels

4km(LA) and 2km(WA) ⊗ 4km(WA) statistical

delay in 4km ⊗ environmental channel

delay in 4km ⊗ ancillary channel

with all other detector groups, with corresponding
observation has been made (preferably a joint
it, to jointly arrive at a reasonable hypothesis why

~ 2000 - 2010

- Merger (CBC) Rates
 - BNS, BBH, (NSBH)
- CBC Source Properties
 - Masses, Spins
 - Spin Tilts, Redshifts

~ 2008 - 2016

- Data Analysis
 - Bayesian Parameter Estimation

Predictions for the Rates of Compact Binary Coalescences Observable by Ground-based Gravitational-wave Detectors

J. Abadie¹, B. P. Abbott², R. Abbott³, M. Abernathy⁴, T. Accardi⁵, F. Acernese⁶, G. Adams⁷, R. Adhikari⁸, F. Ajami⁹, B. Allen¹⁰, G. Allen¹¹, E. Amadio Virani¹², R. S. Anand¹³, S. B. Anderson¹⁴

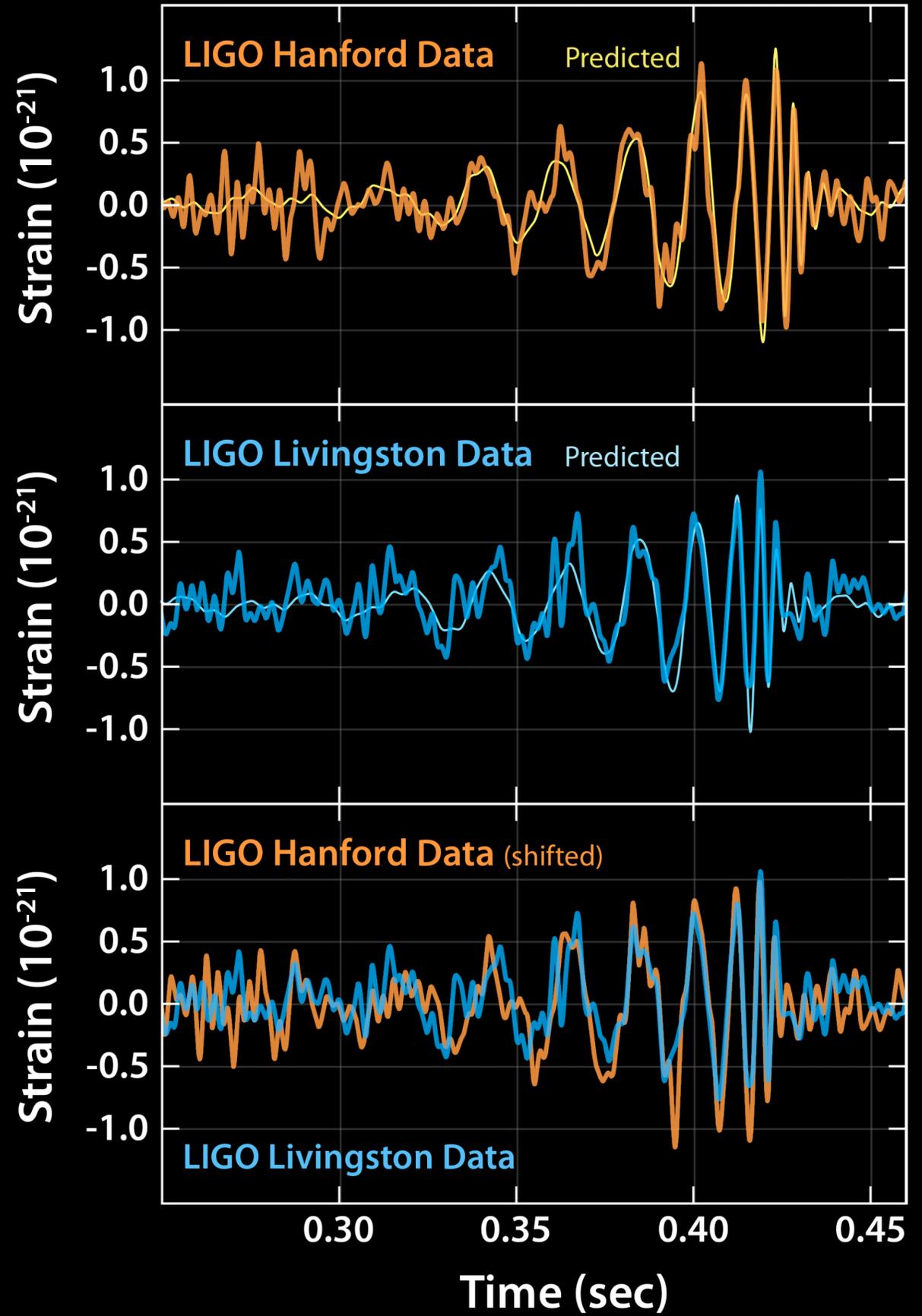
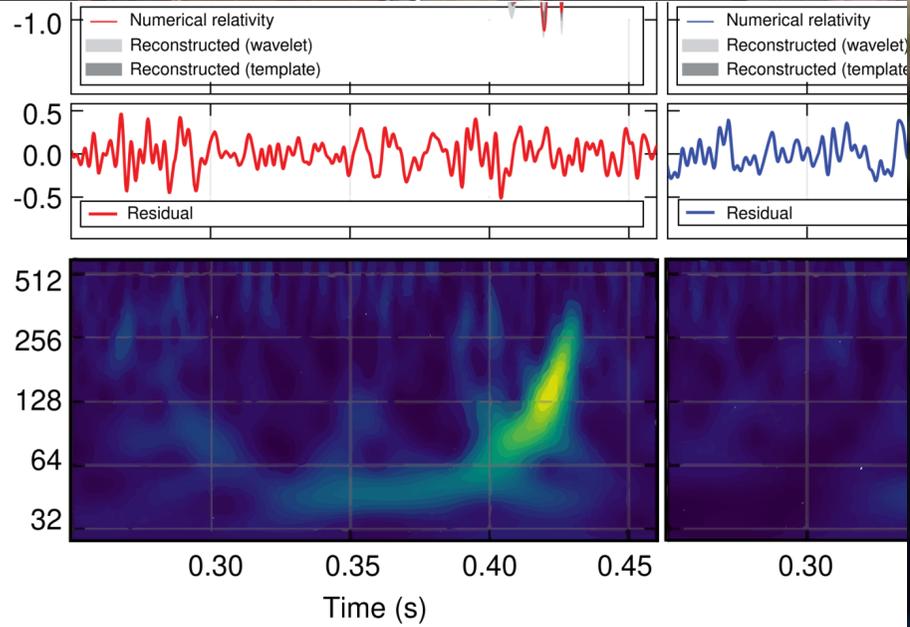
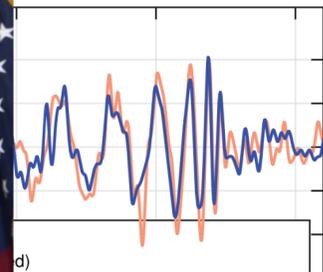
~ 2015 - present

- Detector Characterization
 - Gravity Spy
- Data-driven Astrophysical Interpretation
- Astrophysical Source Properties

GW150914

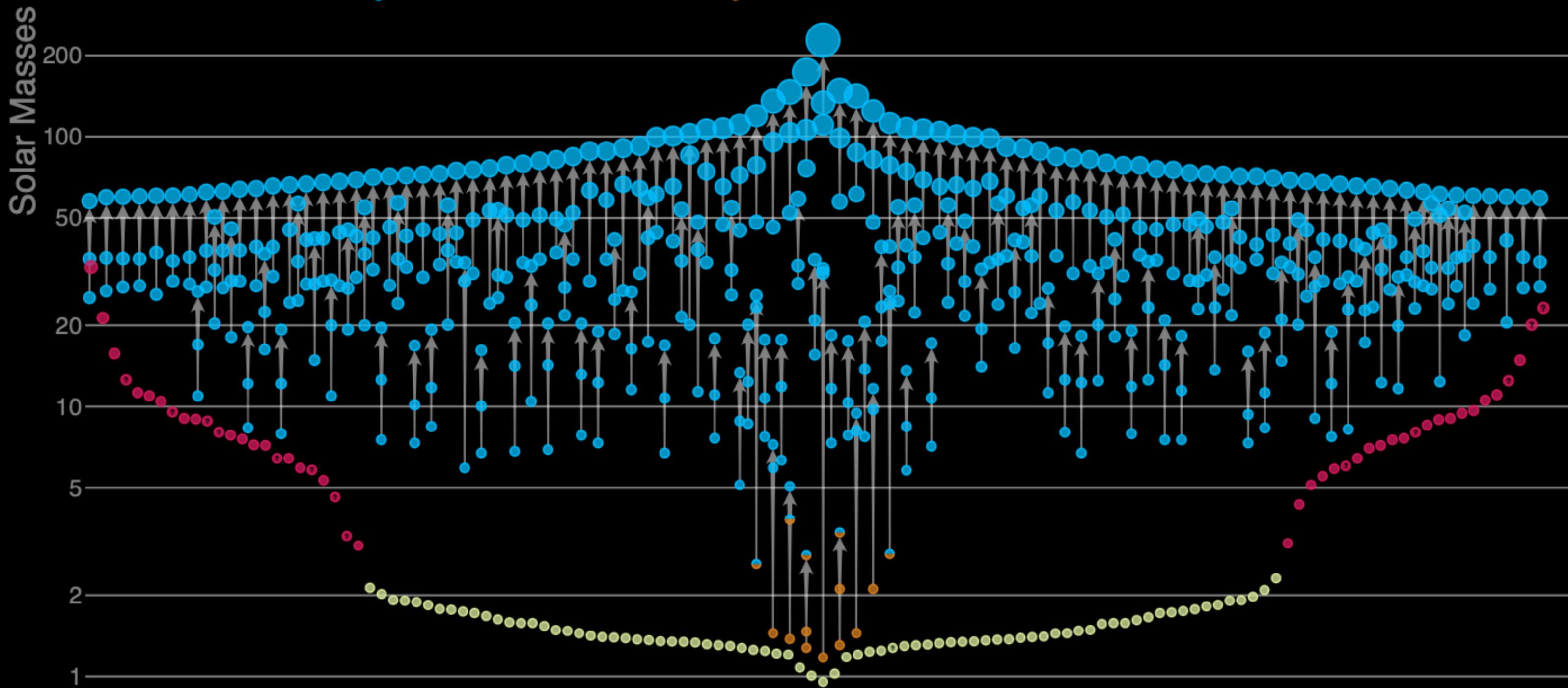


Louisiana (L1)



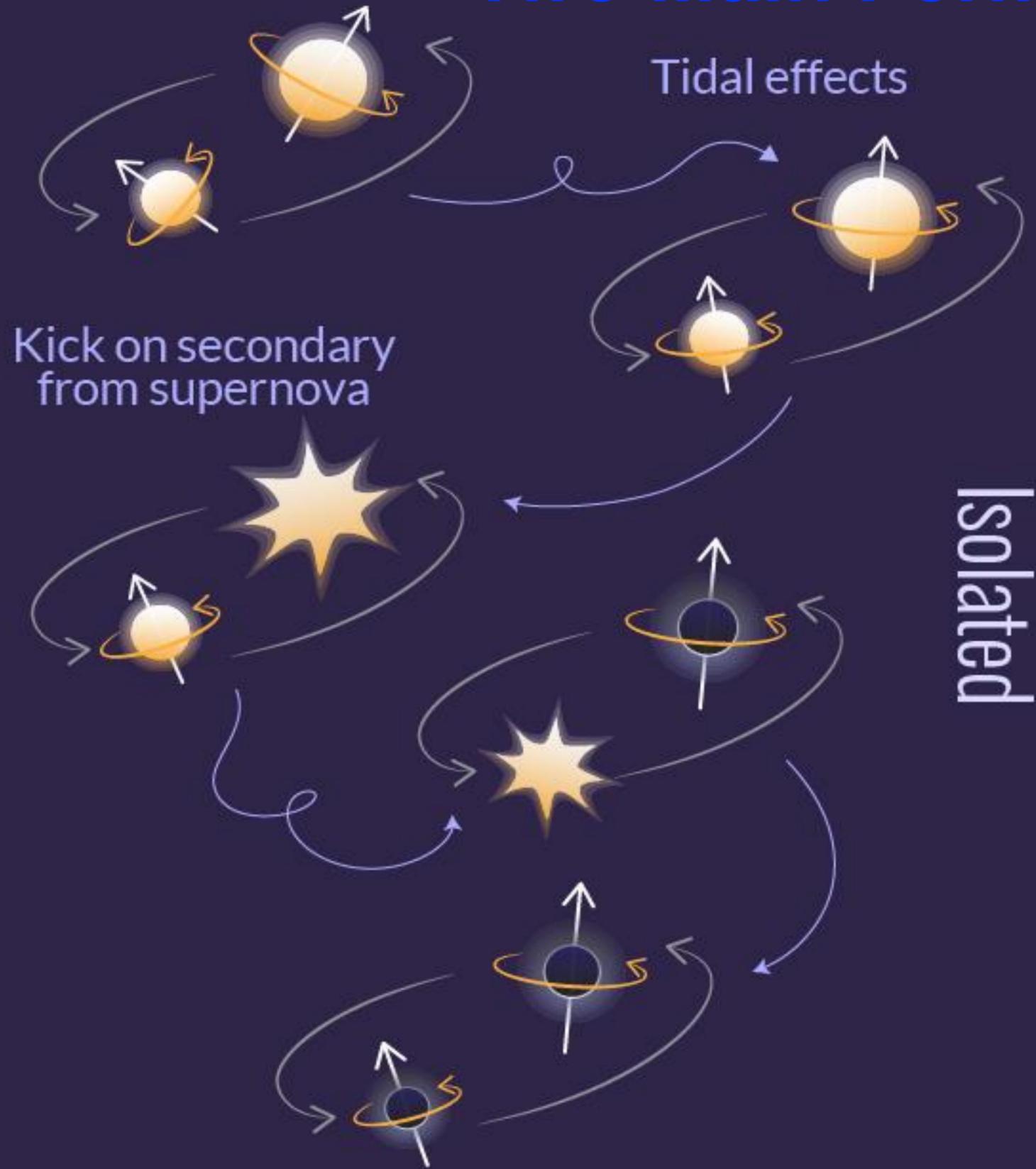
Masses in the Stellar Graveyard

LIGO-Virgo-KAGRA Black Holes *LIGO-Virgo-KAGRA Neutron Stars* *EM Black Holes* *EM Neutron Stars*

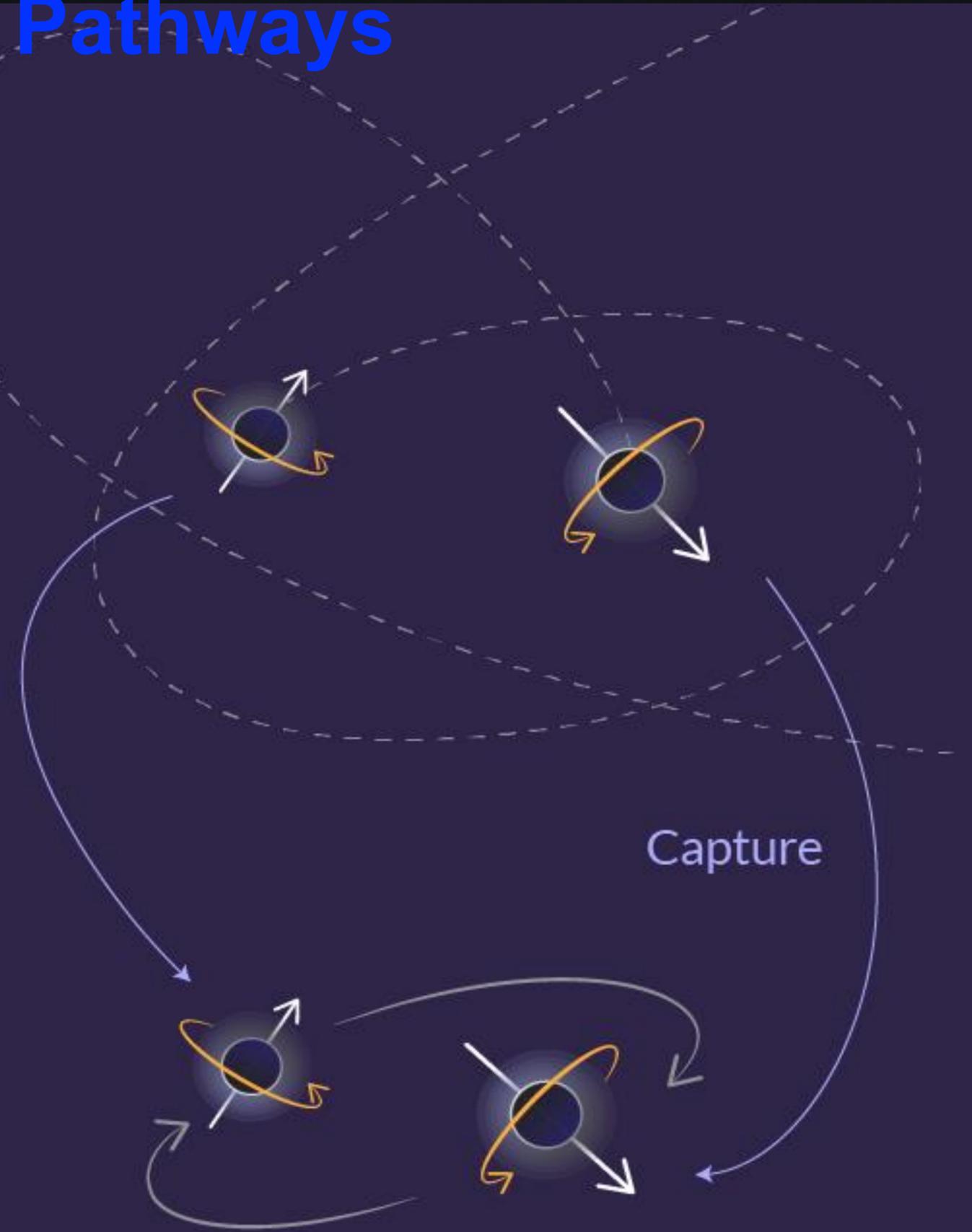


LIGO-Virgo-KAGRA | Aaron Geller | Northwestern

Two Main Formation Pathways

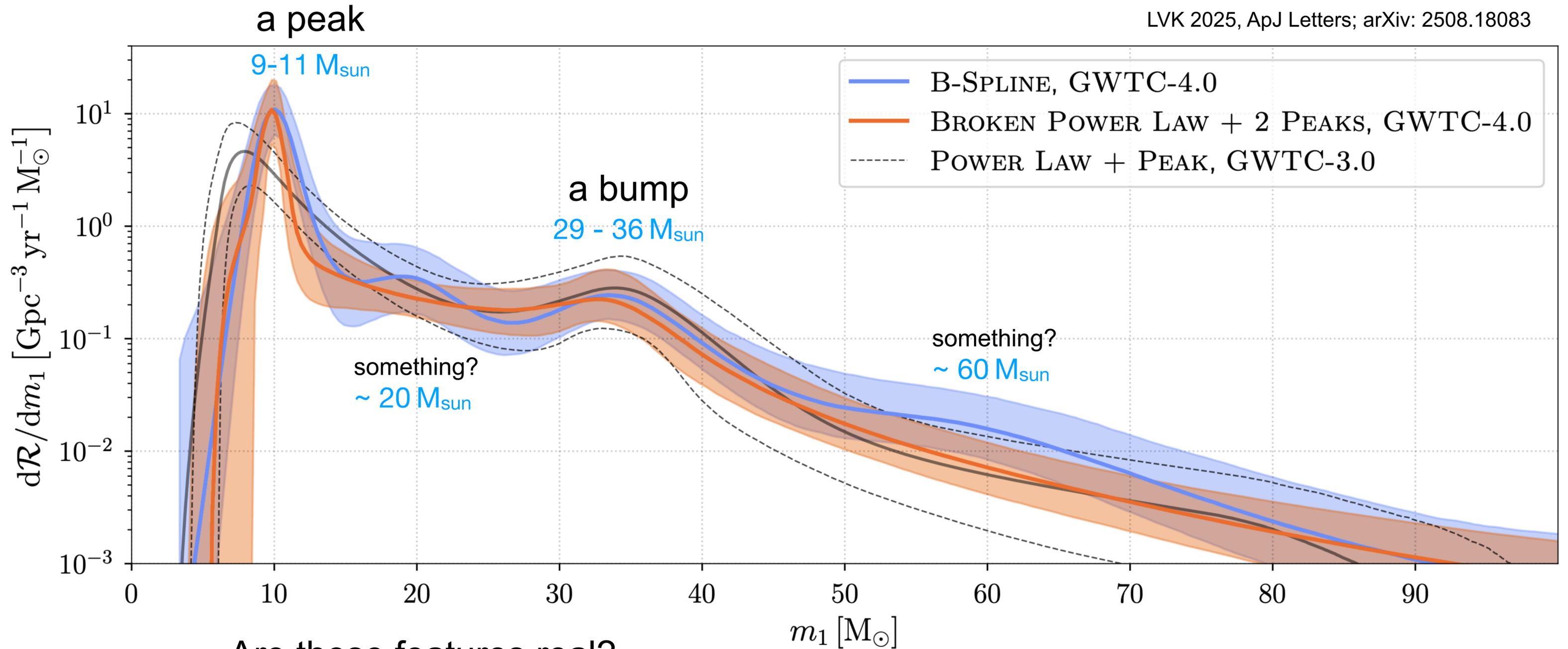


Dynamical



First come the masses ...

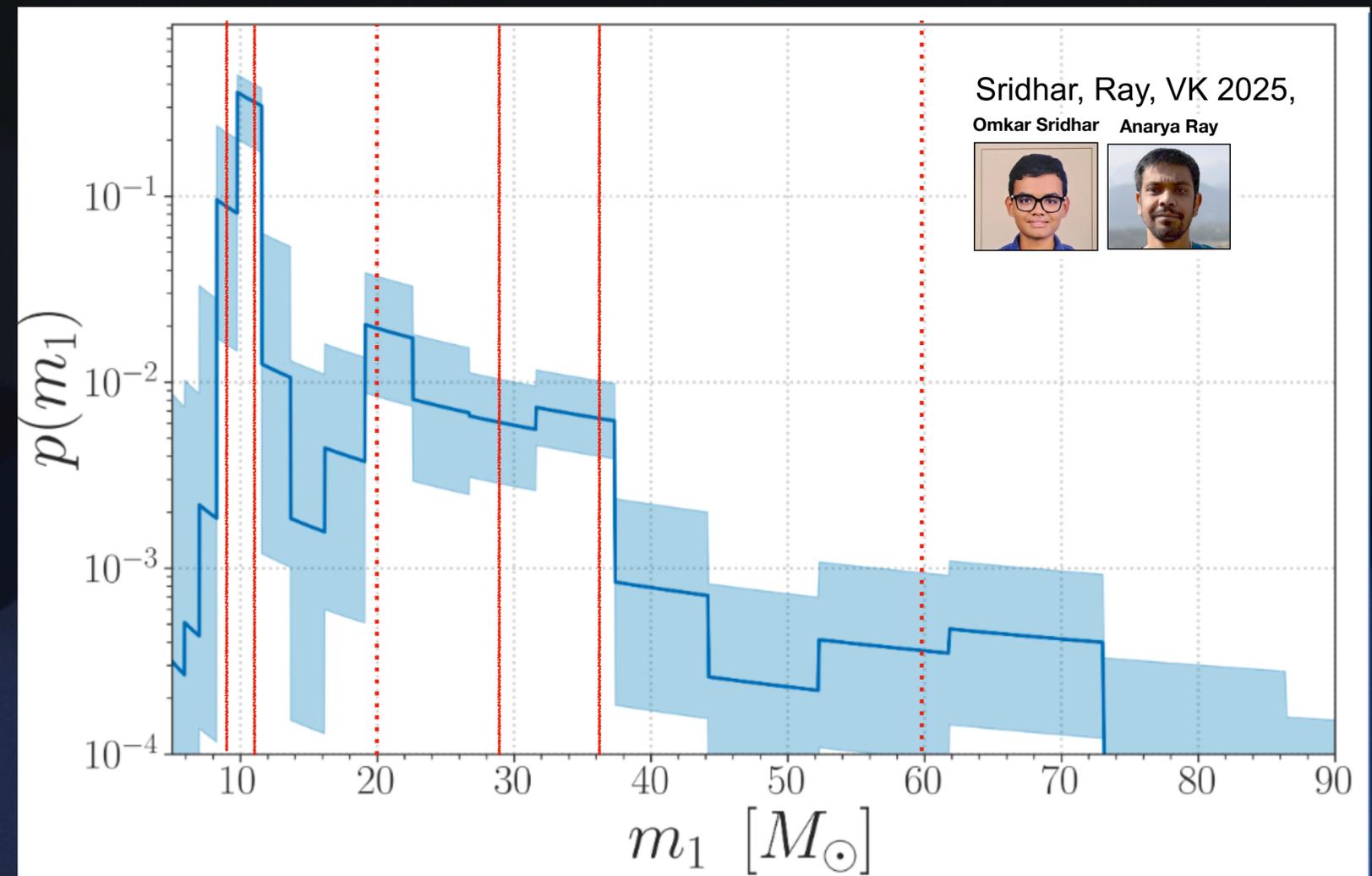
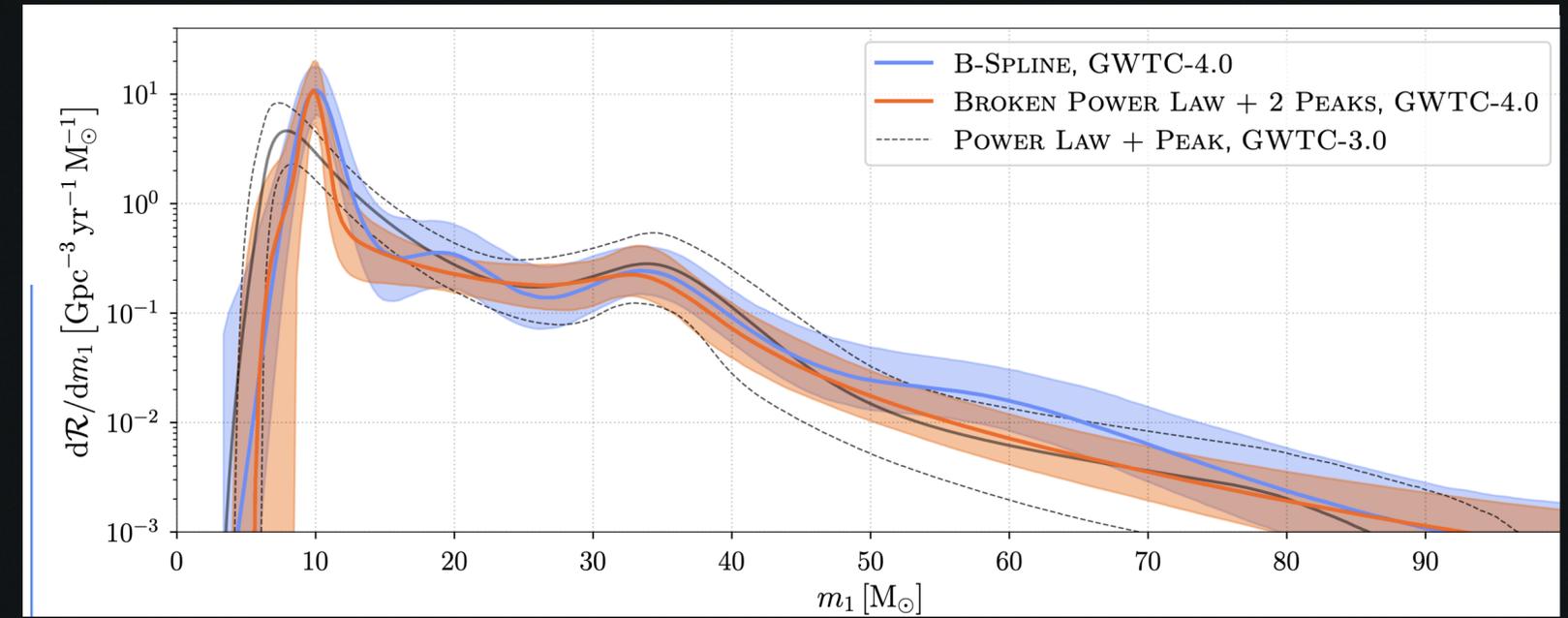
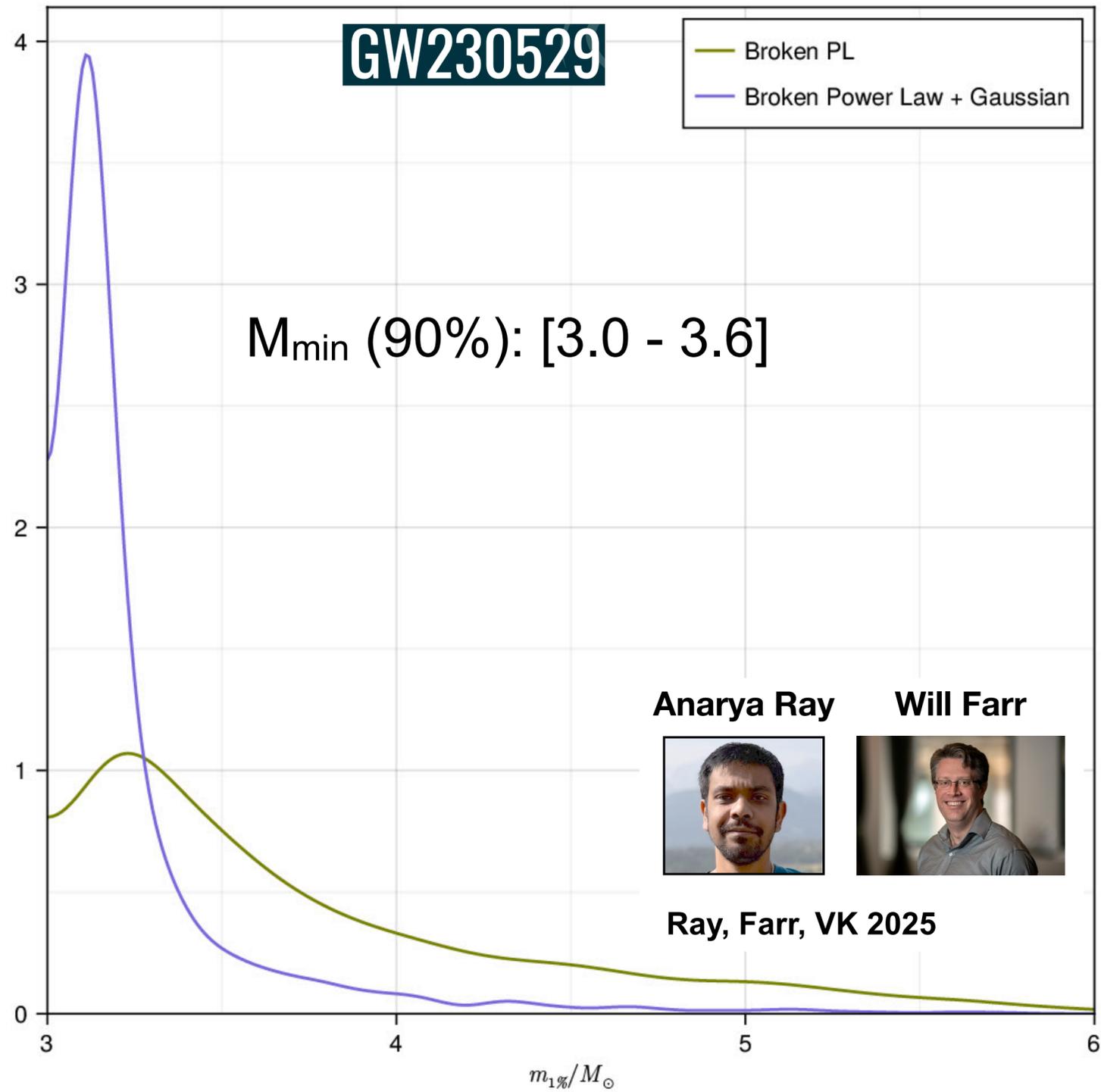
LVK 2025, ApJ Letters; arXiv: 2508.18083



Are these features real?

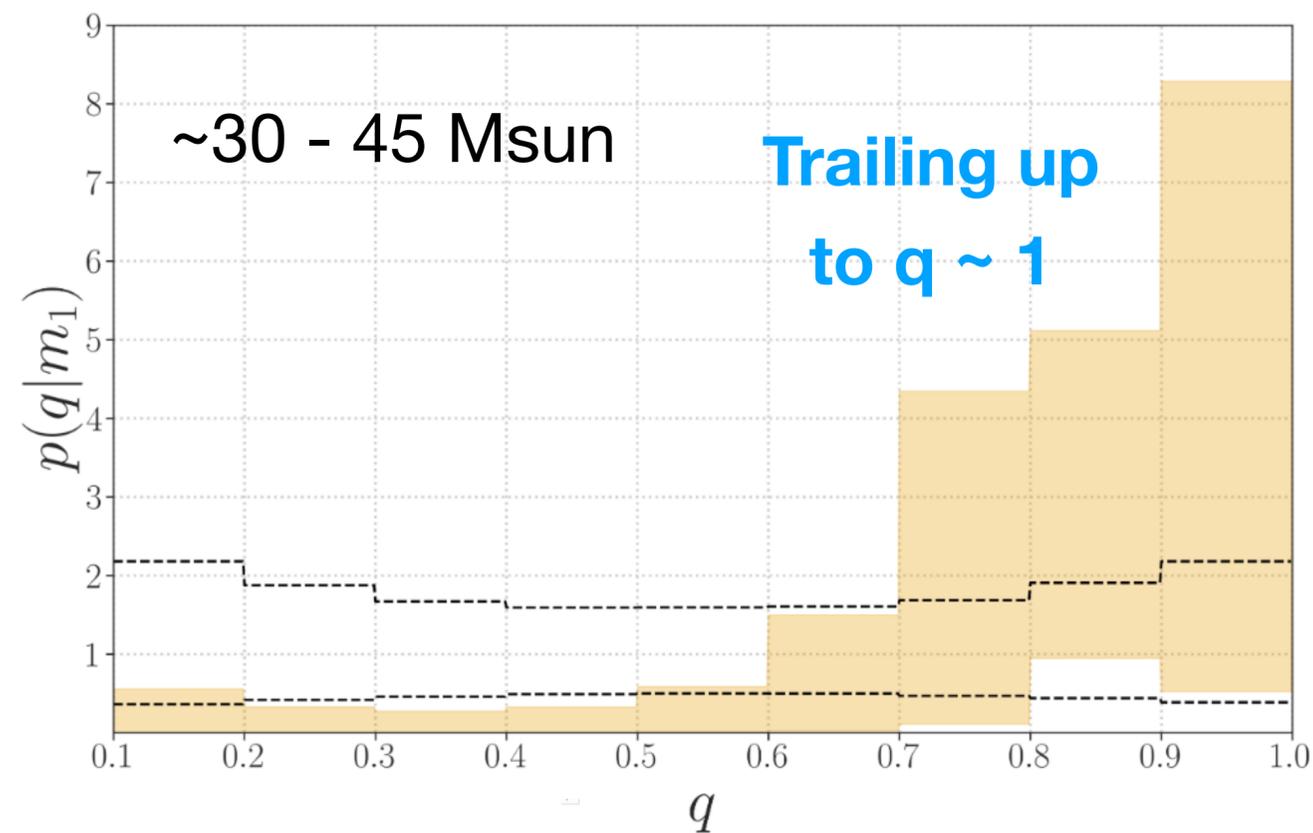
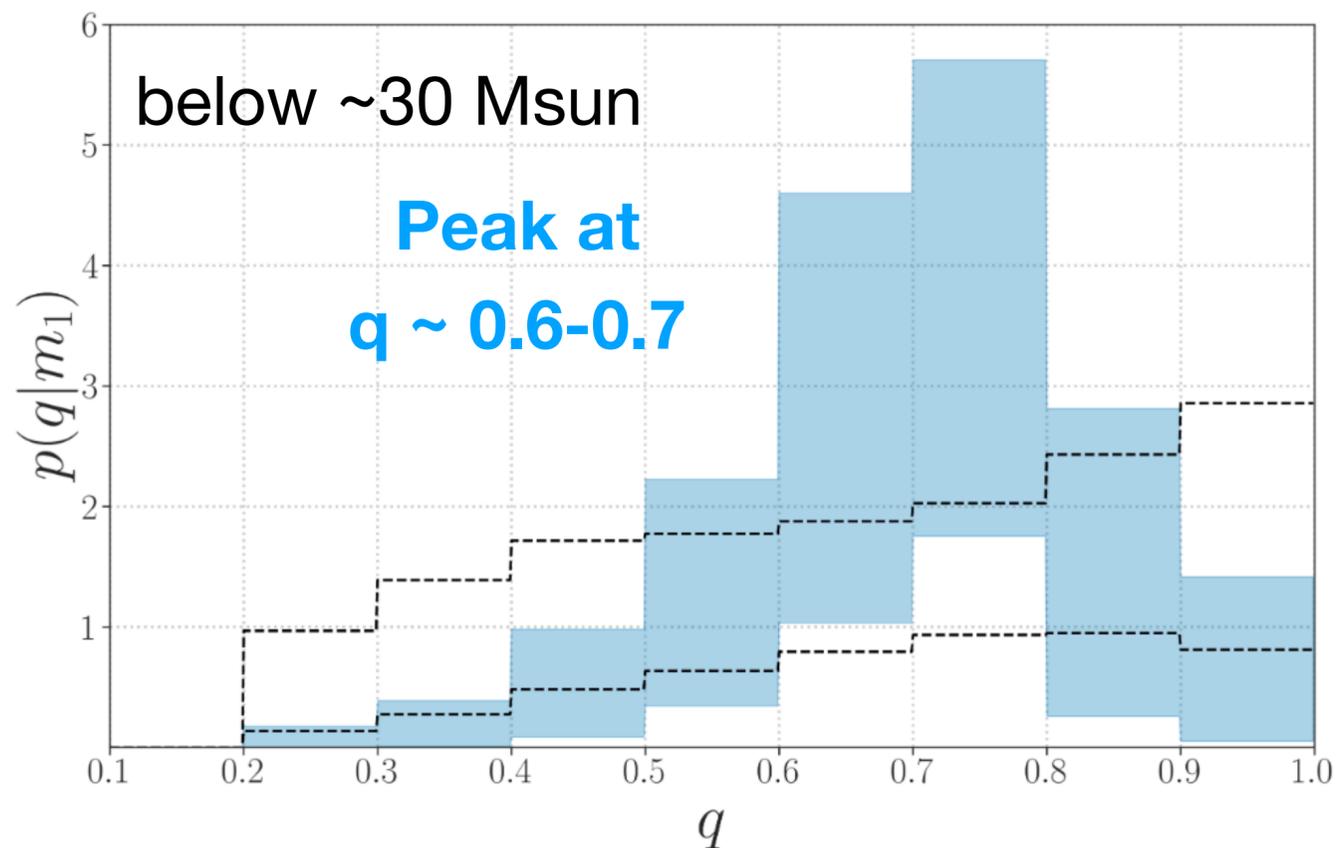
What is their physical origin?

Another look at low-mass BHs: No evidence for a gap



Let's unpack things: mass ratios

priors
.....

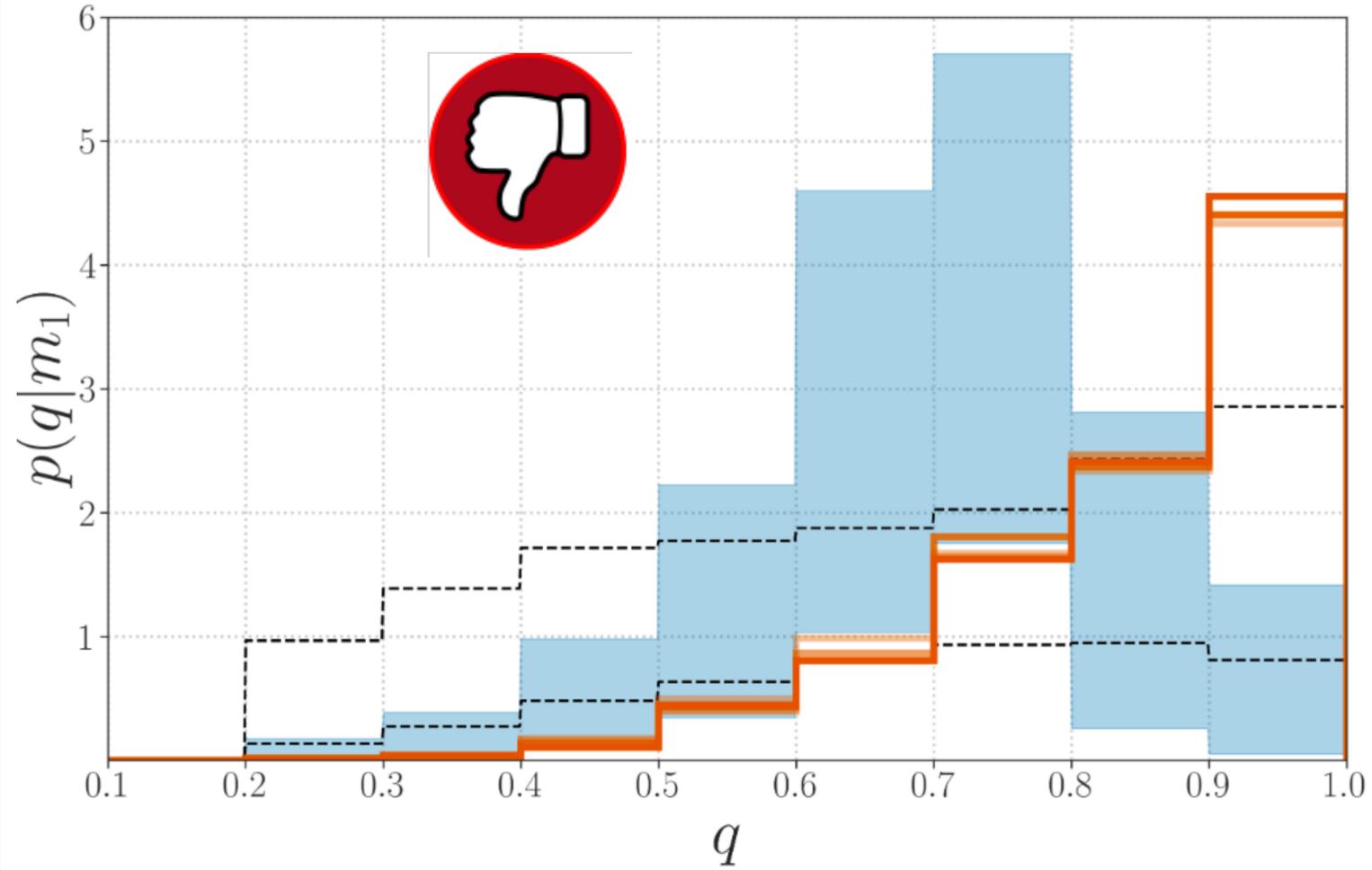


Also in Godfrey+ from GTWC3
and in LVK O4a

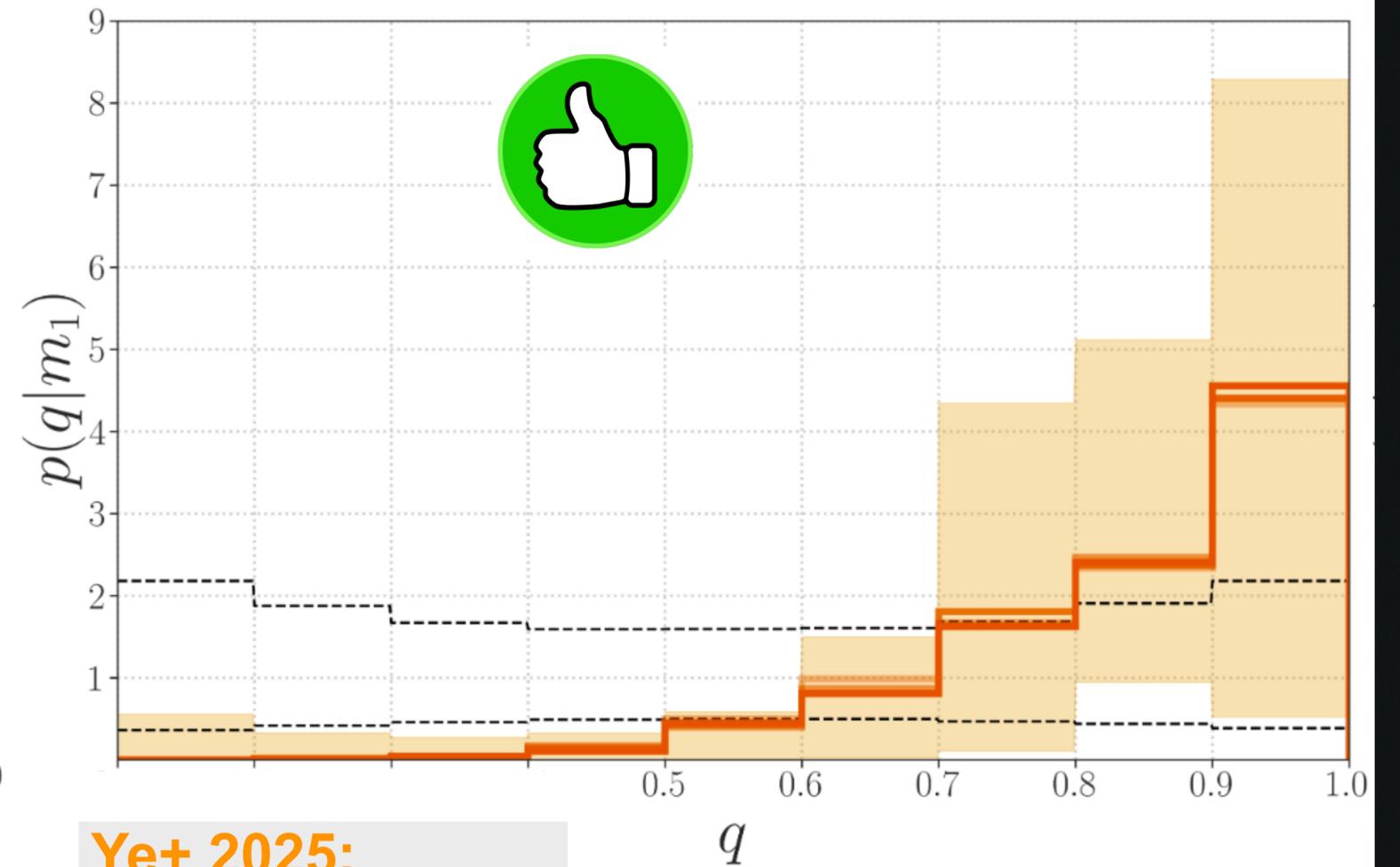
Also in Godfrey+, LVK O4a
for masses above 15Msun

and in Banagiri+ 2025 for 20-40

M_1 below $\sim 30 M_{\text{sun}}$



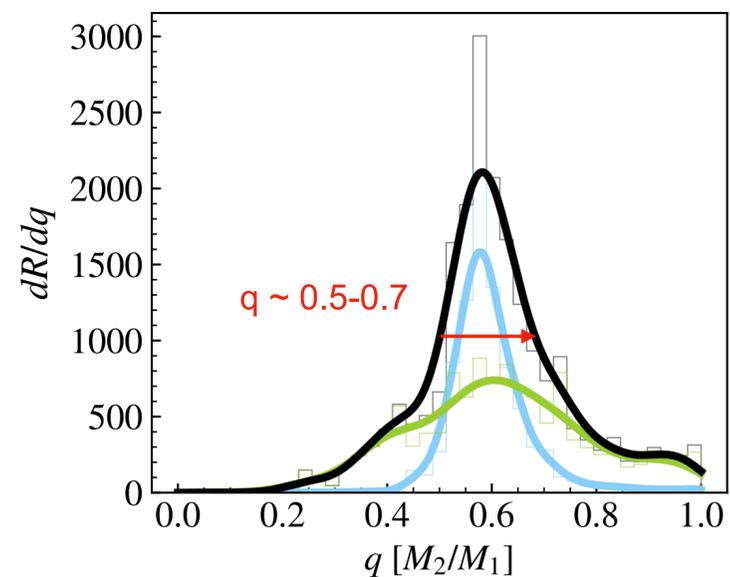
$M_1 \sim 30 - 45 M_{\text{sun}}$



Ye+ 2025;
arXiv:2507.07183

isolated binary models

Gallegos-Garcia, VK,+ 2025, in prep



Thank you, Rai!

On Thu, 29 Sep 2022, Vicky Kalogera wrote:

Dear Rai,
A little birdie told me it is your 90th birthday today! Very happy birthday, I hope you get to celebrate with family and close friends and you get all special treatment!
I send you my best wishes and my many, many thanks for all the ways you have impacted my path. You were singularly important in my decision to join the LSC and I will always remember your words in your office almost 25 twenty years ago and I am greatly appreciative you visited Northwestern and spent time with us all. I am sure you have also done things I don't know about, but you have also been a critical influence on me without your knowing, as I watched you all these in big and small moments, events, and interactions.
To say that you are an inspiration is an understatement. Big Hugs!
Vicky

On Sep 29, 2022, at 10:36 AM, Rai Weiss wrote:

Vicky,
Thank you for the note. I am an astronomer, took interest in wave astronomy was a nice surprise in its dark times before discovery of wave detectors. I hear a rumor from the press that is a chance you might be interested in science and reality of the wave detectors. It is an important topic for astronomy and encourage you to tell you what I know about

On Oct 4, 2022, at 10:36 AM, Rai Weiss <weiss@ligo.mit.edu> wrote:

Vicky,
Thanks for the information. That movie you sent must have happened because you or your kids were studying the piano and had left the music open to the C major prelude (the only one in the well tempered one can just read and try to play). Did anyone in your family go on and enjoy the pleasure of playing?

From: Rai Weiss <weiss@ligo.mit.edu>

Subject: Re: Best wishes!

Date: October 4, 2022 at 11:07:06 AM CDT

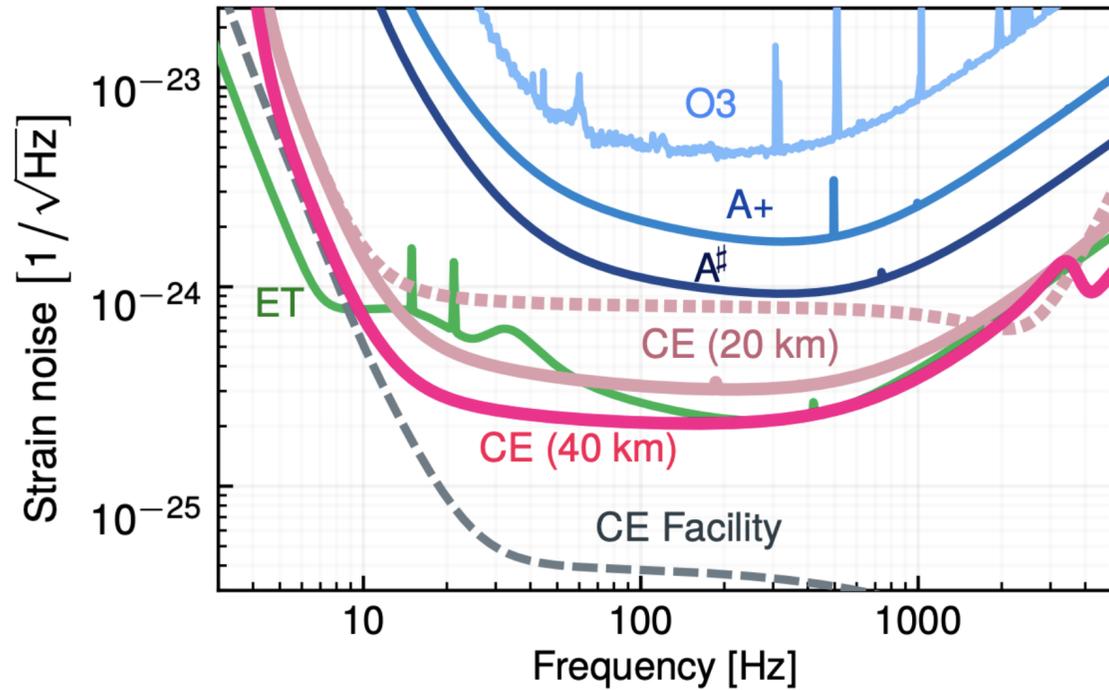
To: Vicky Kalogera <vicky@northwestern.edu>

Resent-From: <vicky@northwestern.edu>

Vicky,
I bet there is a grand piano in your future. They sound so much better than a spinet or upright. Let's see how Fred's interest grows.
Rainer

Thank you, Rai!

3/13/2024



Rai

Vicky,

I would be honored if you include my note to you and the committee in the documents. If I were to write it again it would emphasize more strongly the possibility that the dark matter in the universe came from the primordial vacuum fluctuations and that these turned into a spectrum of black hole masses. In other words, the dark matter is primordial black holes. I have pulled a small group together at MIT who think this is likely as it would solve several puzzles in cosmology including the time of the formation of the first stars now discovered by JWST observations. A 40km Cosmic Explorer may also have a good chance of establishing if there are primordial black holes of the types we are now observing with LIGO but at times earlier than the first stars. LISA is not sensitive enough to do this (the BH mass is too small) nor will pulsar timing. I would be happy to talk with you about the various puzzles and see if your group would be interested in thinking about black holes being dark matter. The idea for this is Stephen Hawking's, I just have become a devotee.

I want to thank you again for taking on the difficult question of the future for gravitational wave research.

Rai to Me

3/29/2024

Vicky,

Your committee report could not have been better for the future of gravitational wave astronomy. I am delighted it was accepted by the parent MPS committee unanimously. Furthermore, you answered the only possibly hostile member of that committee masterfully by saying yes improvements can be made to the detectors but they would be ever so much more important scientifically if they were made on a 40km detector.

Thank you again for taking the committee chairmanship.

Rainer



MPSAC ngGW Subcommittee

