

The Diversity of Gravitational-Wave Transients

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CIERA Board of Visitors Research Assistant Professor
The Transient and Variable Universe, UIUC

June 21, 2023

Northwestern

C I E R A

CENTER FOR INTERDISCIPLINARY EXPLORATION
AND RESEARCH IN ASTROPHYSICS

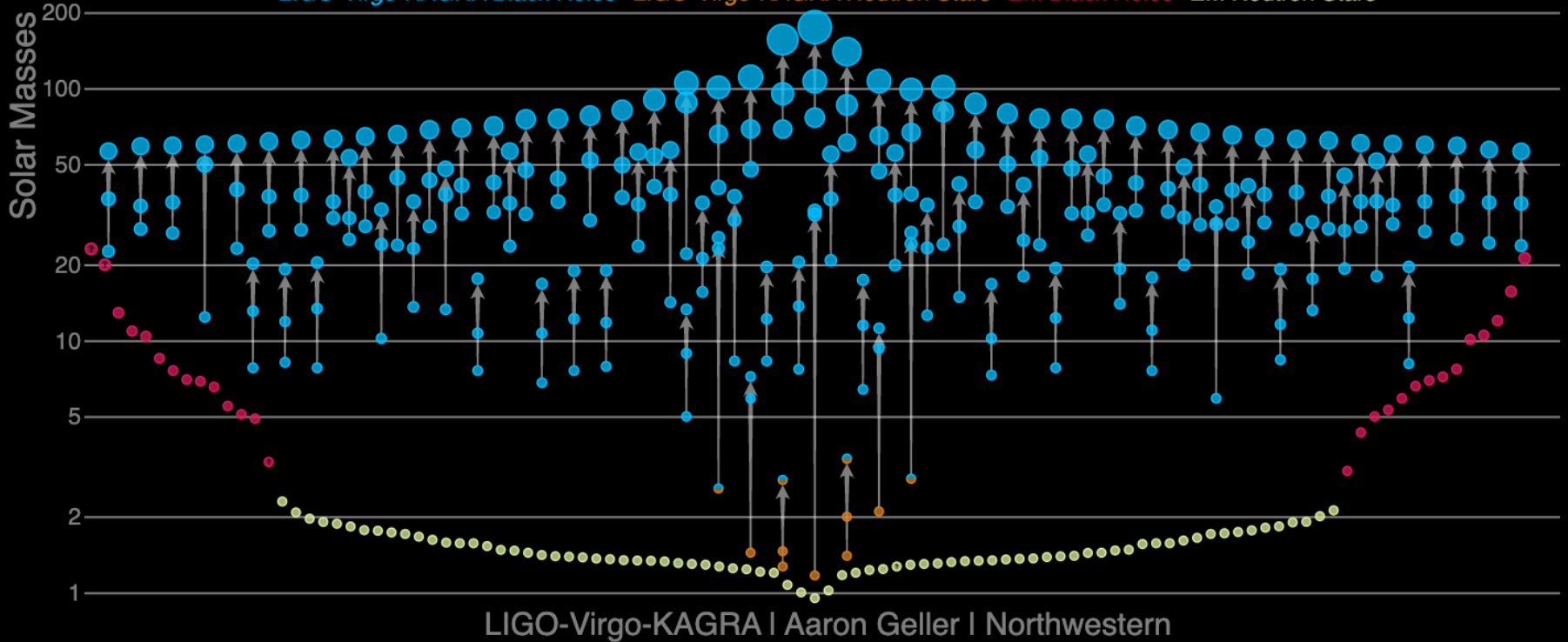


@actualdrdoctor



Masses in the Stellar Graveyard

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



Now

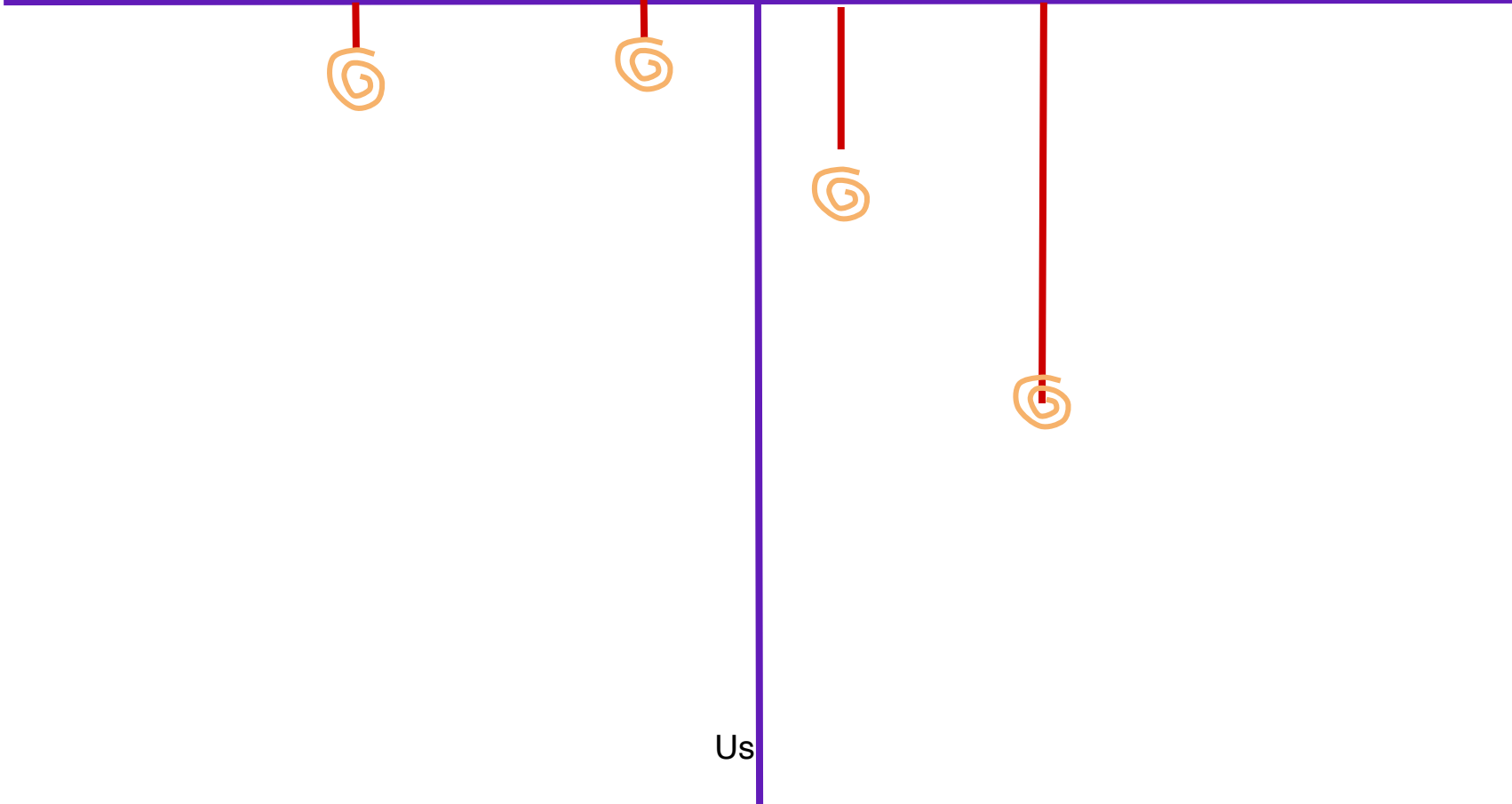
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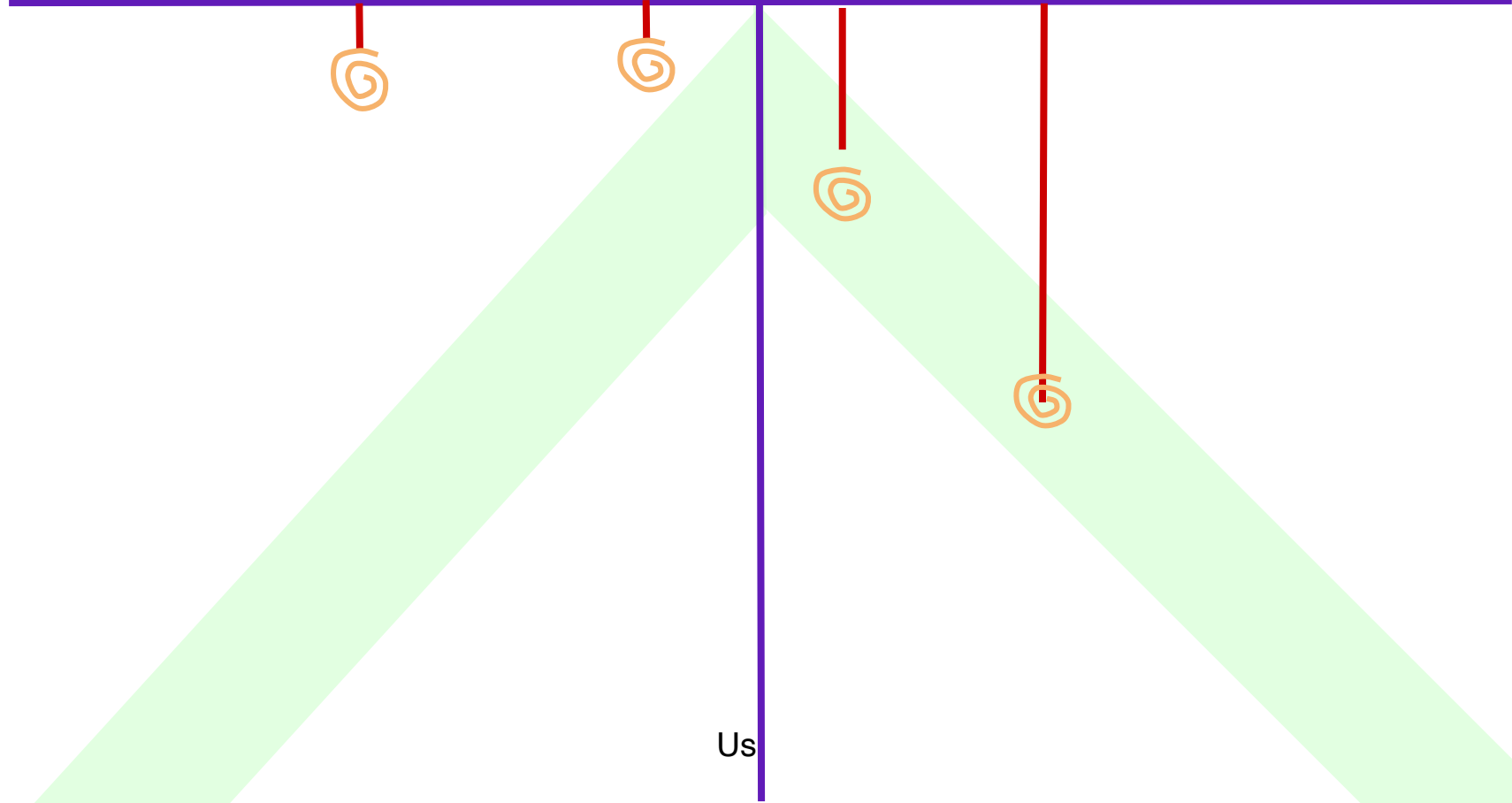
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Now



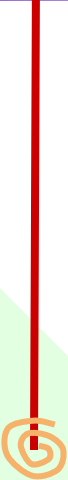
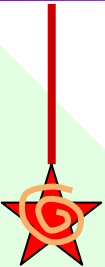
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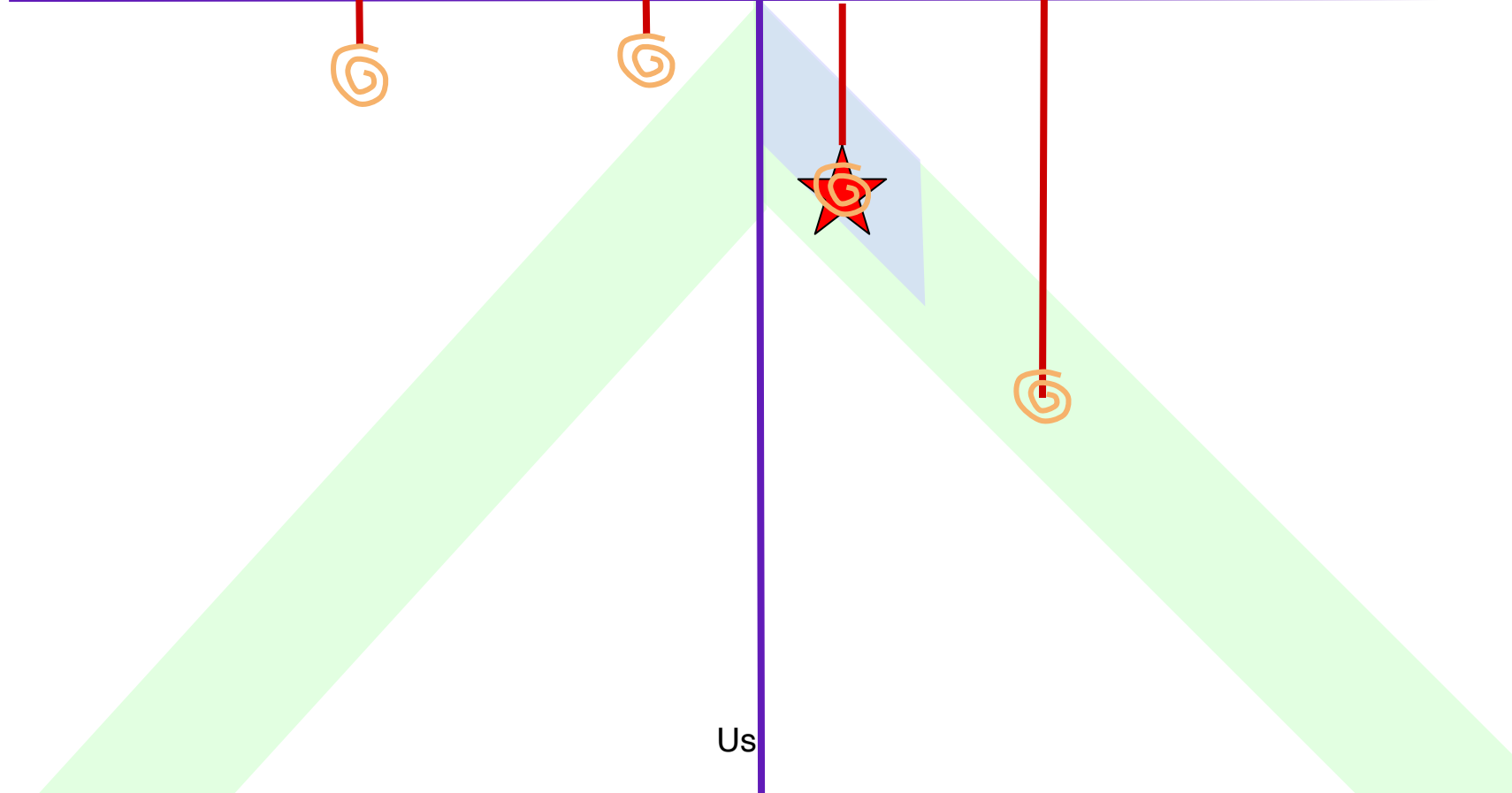
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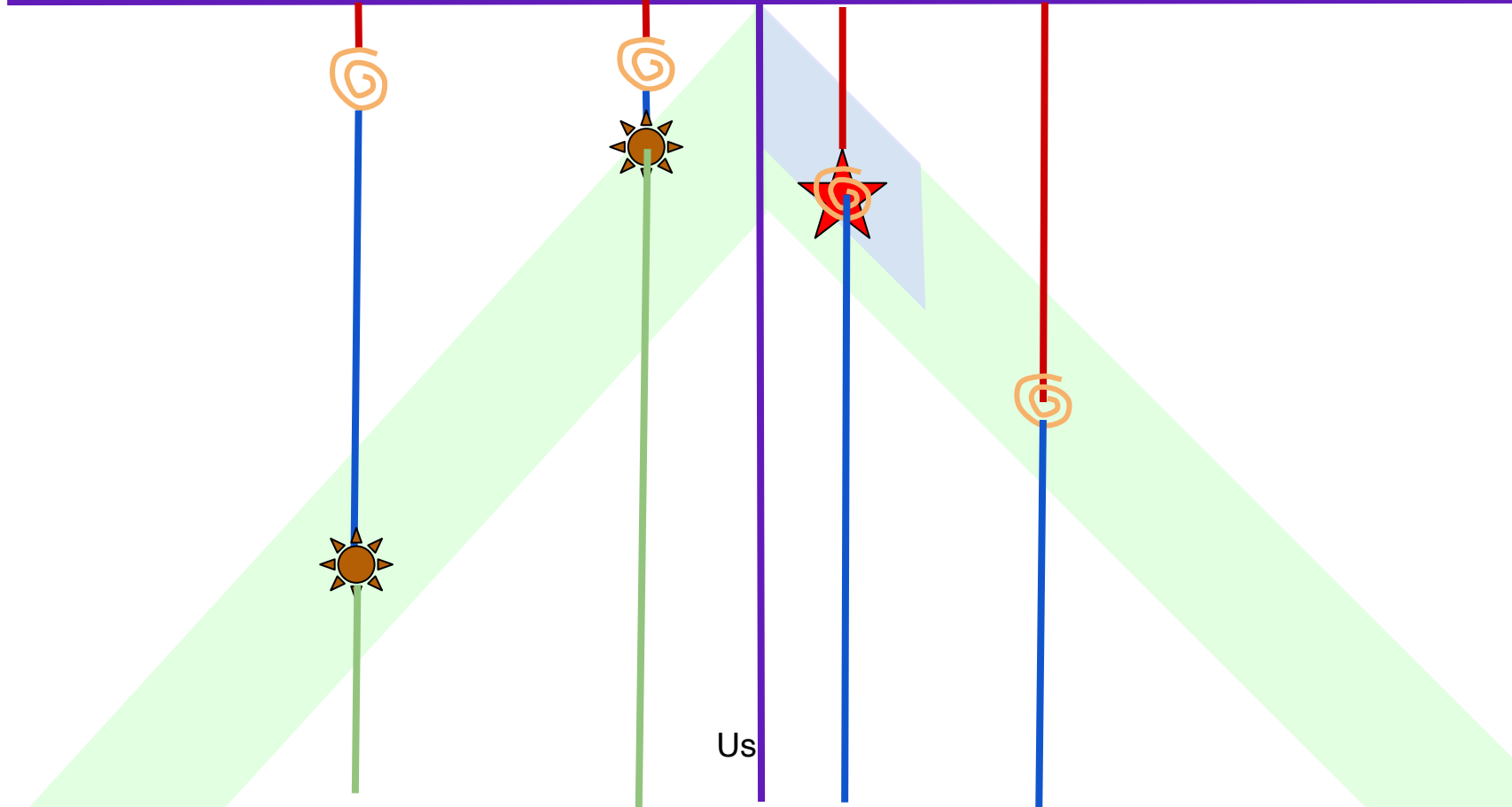


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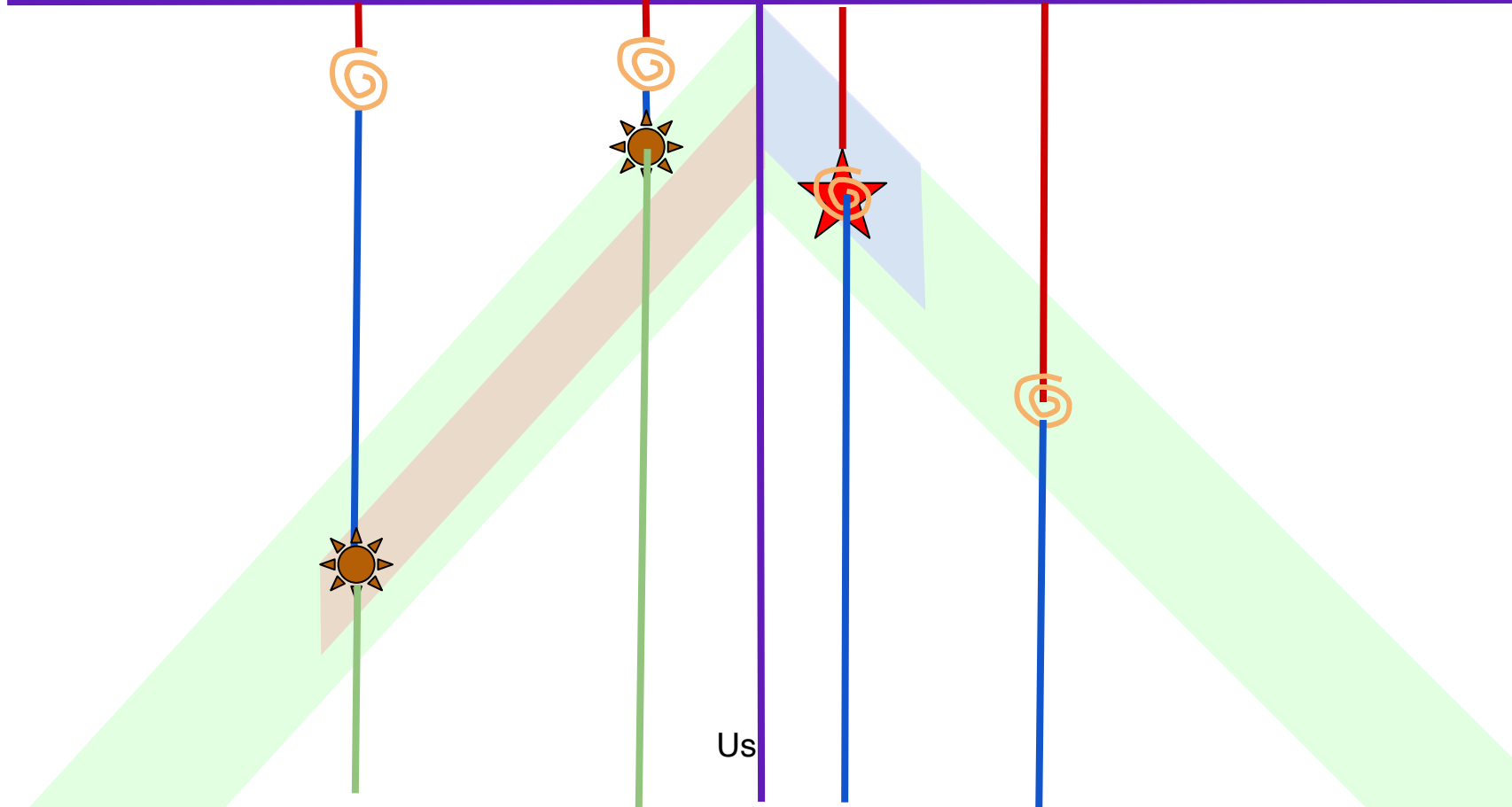


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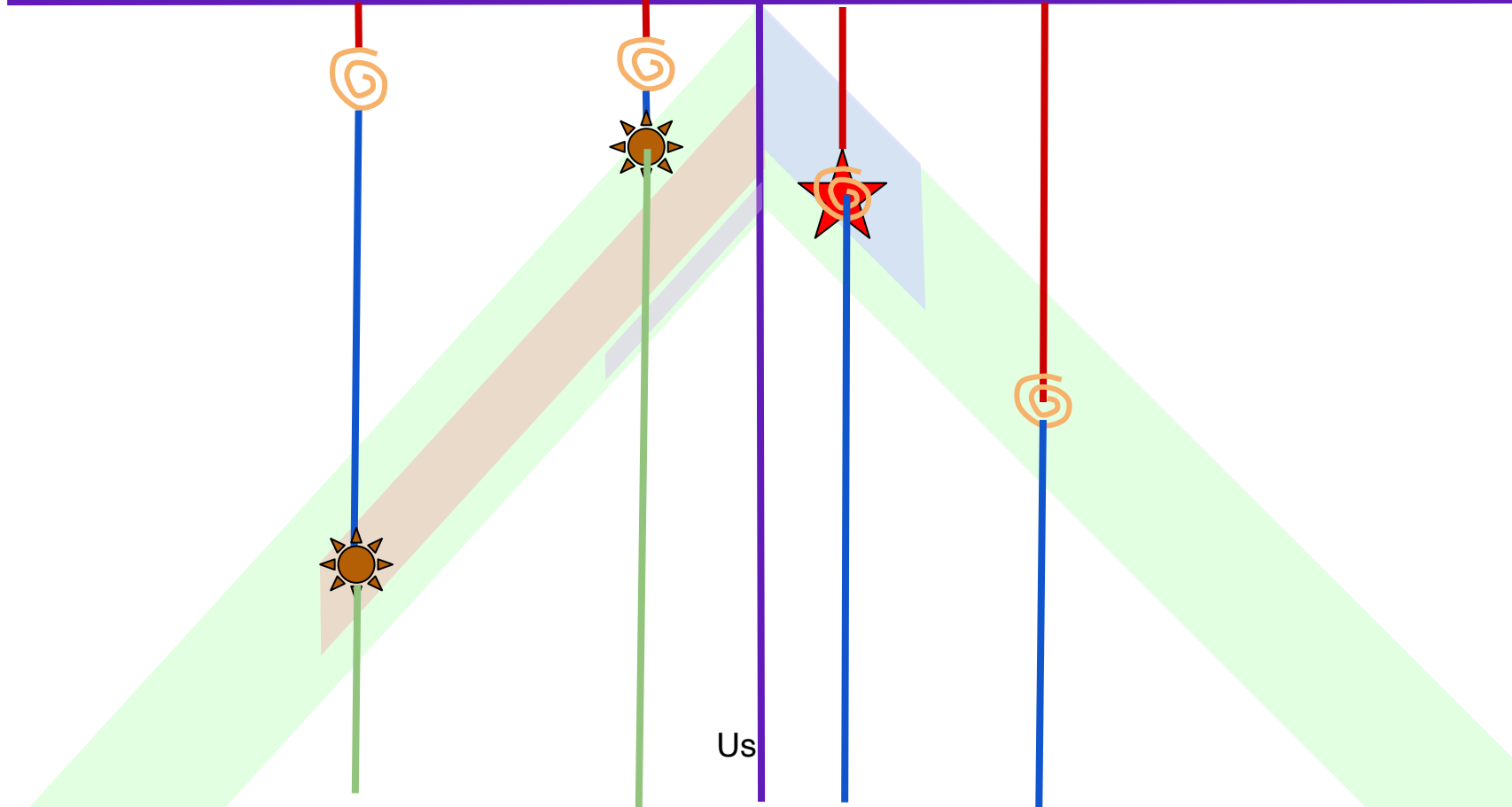


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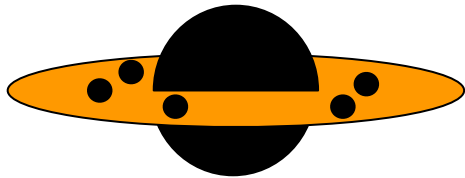
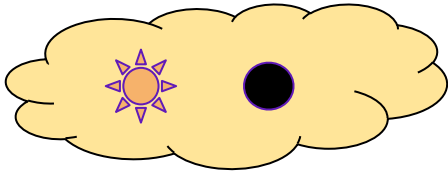
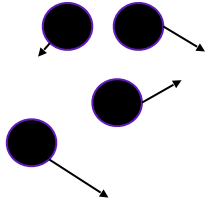
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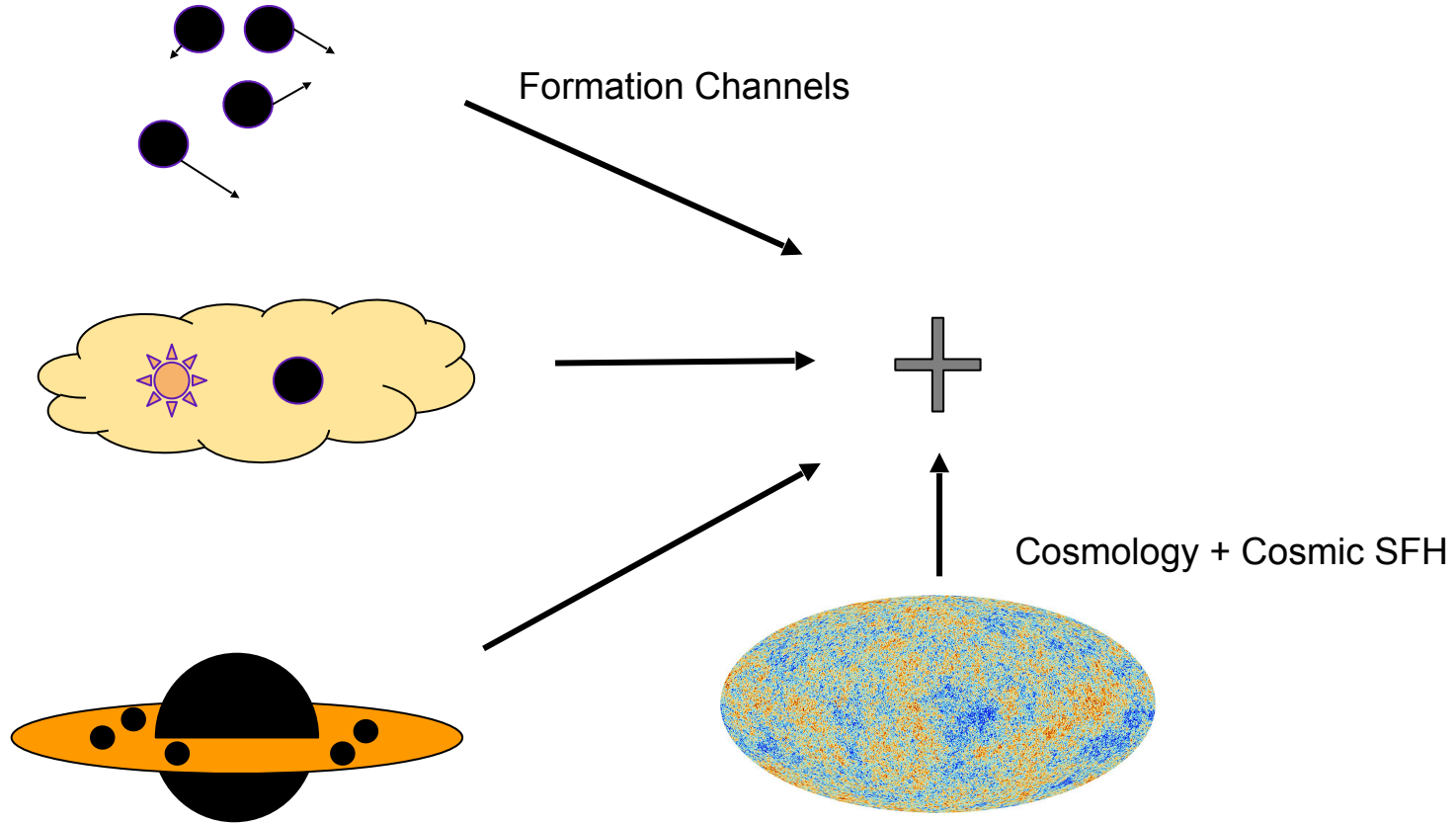
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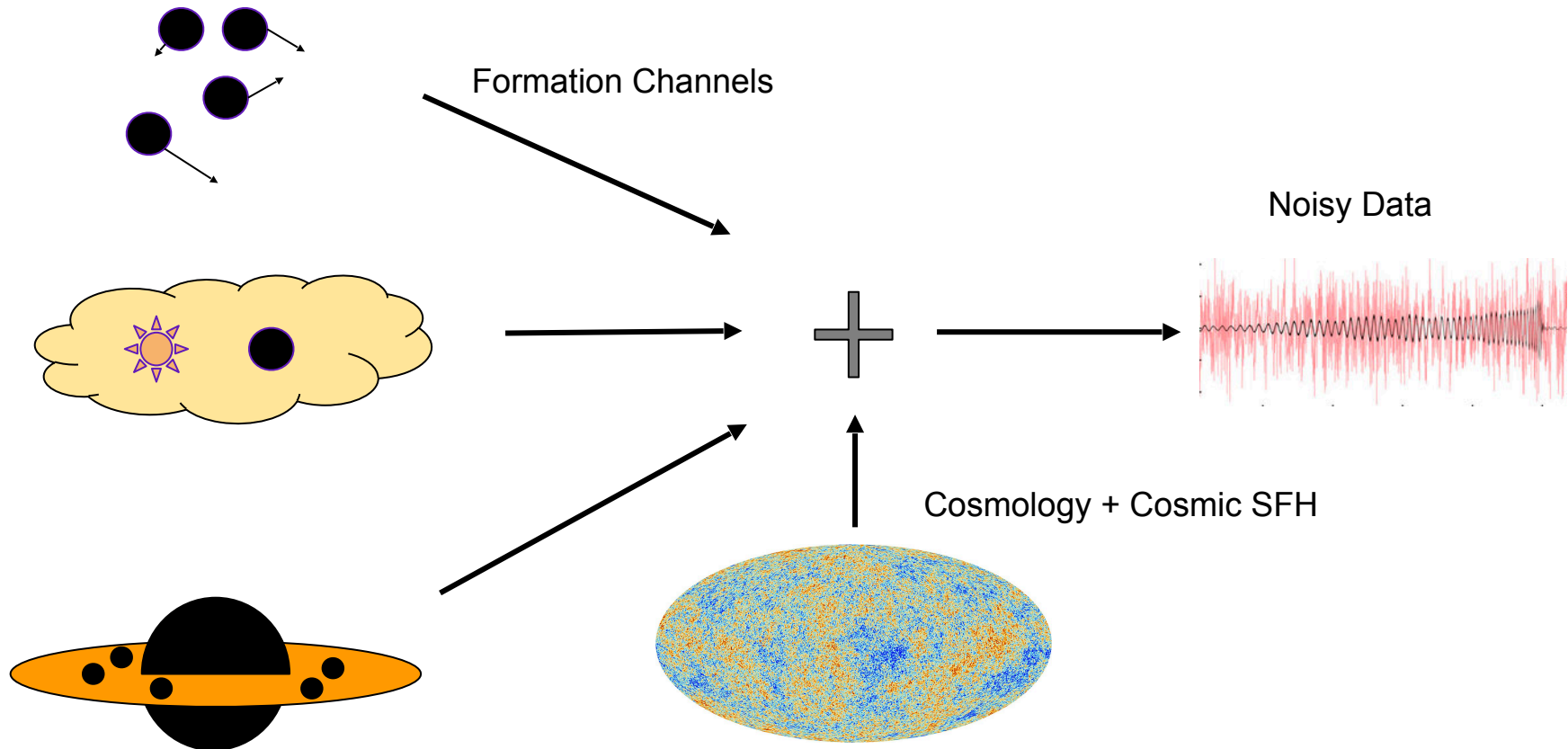
Detailed Astrophysical Processes

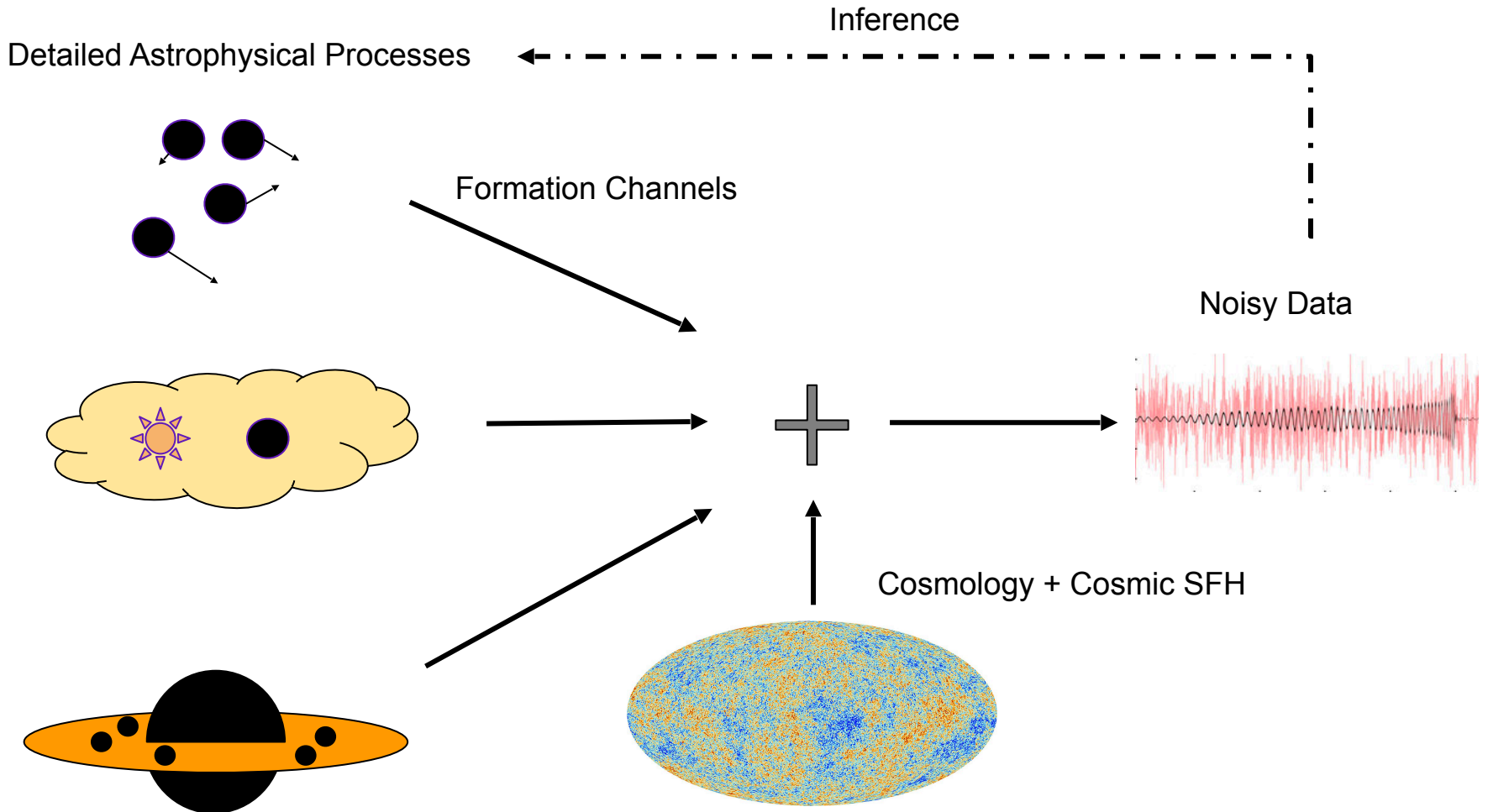


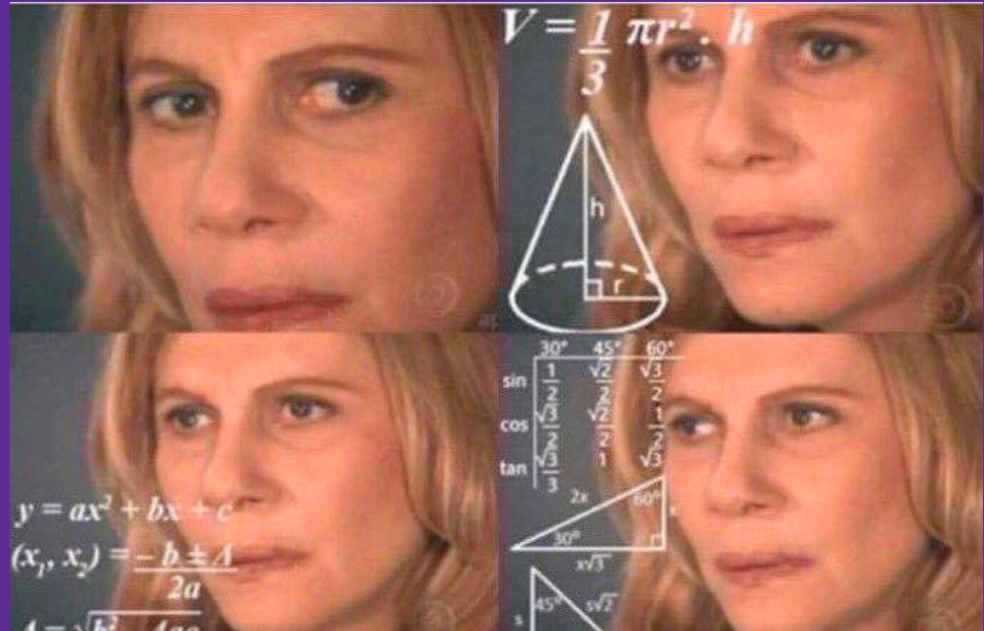
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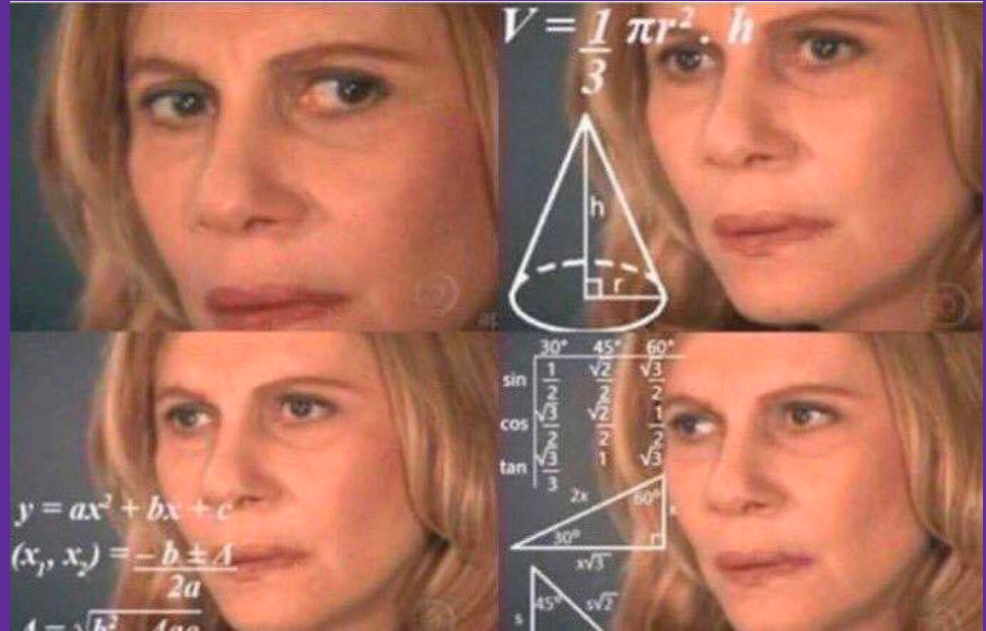
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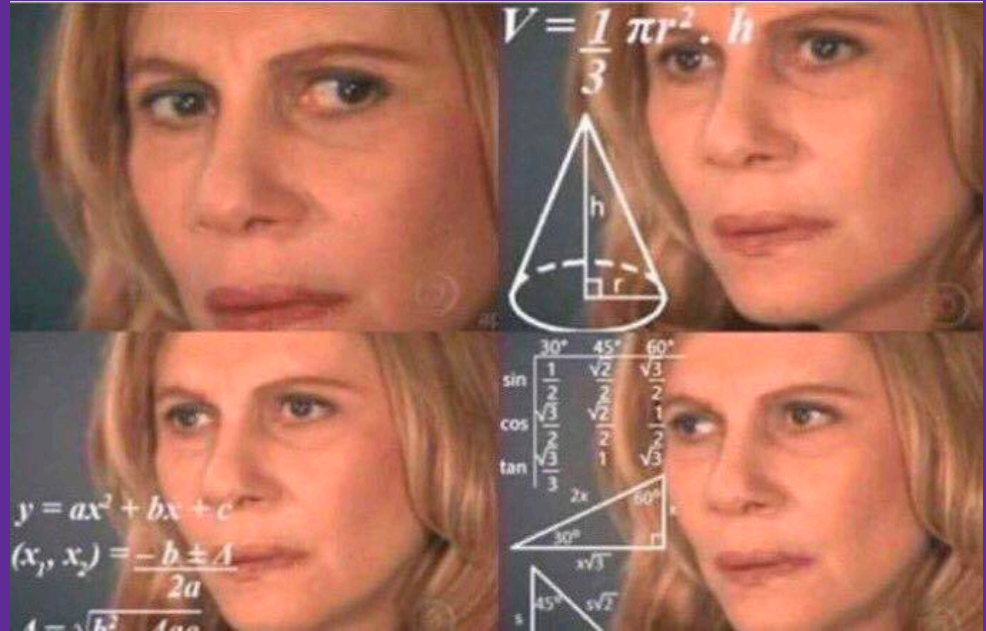




High-Dimensional Source Parameter Space!

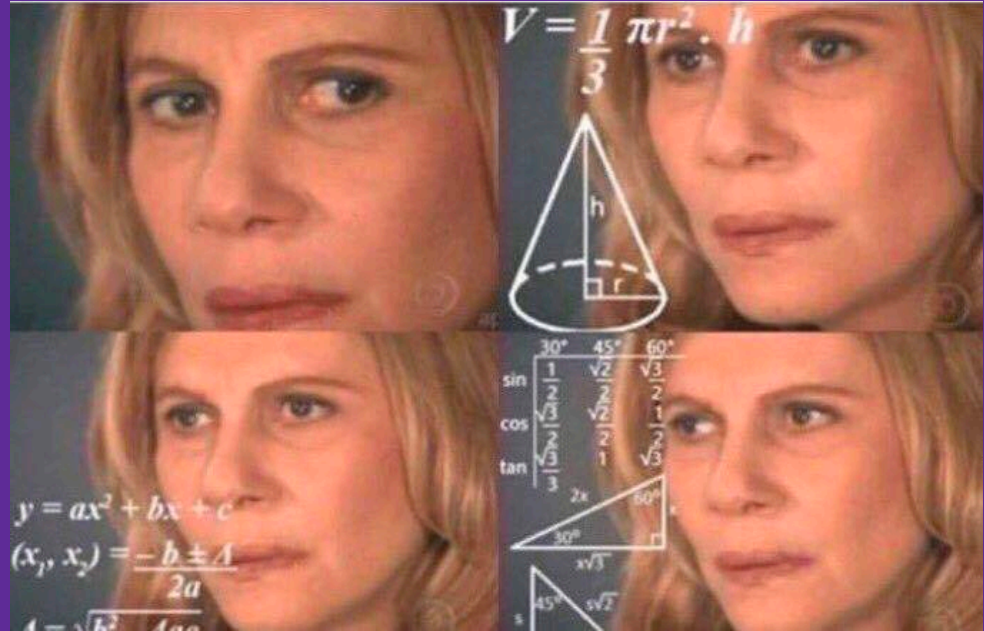


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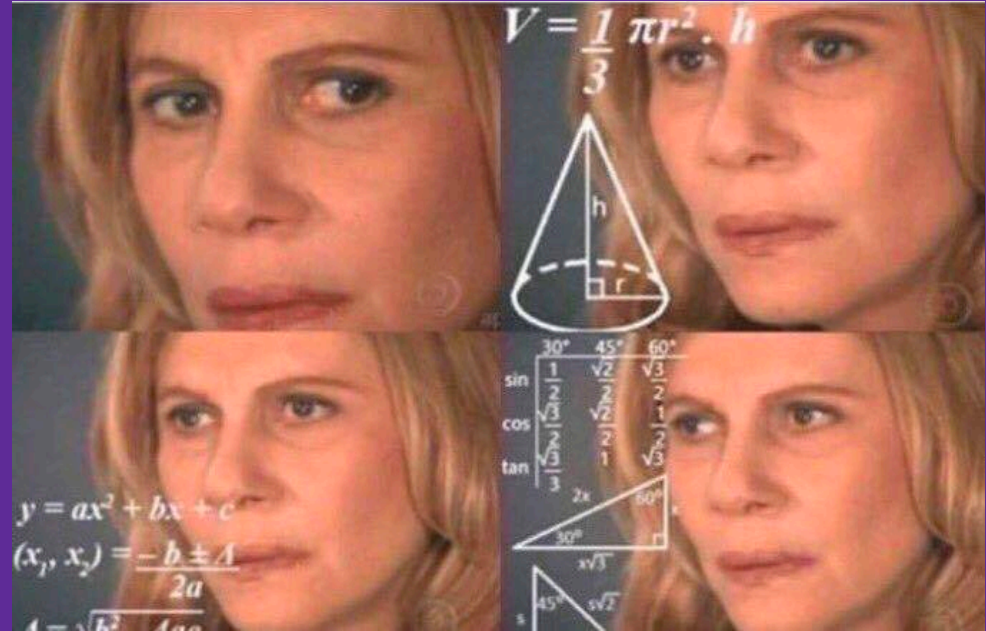
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Systematic Uncertainties!



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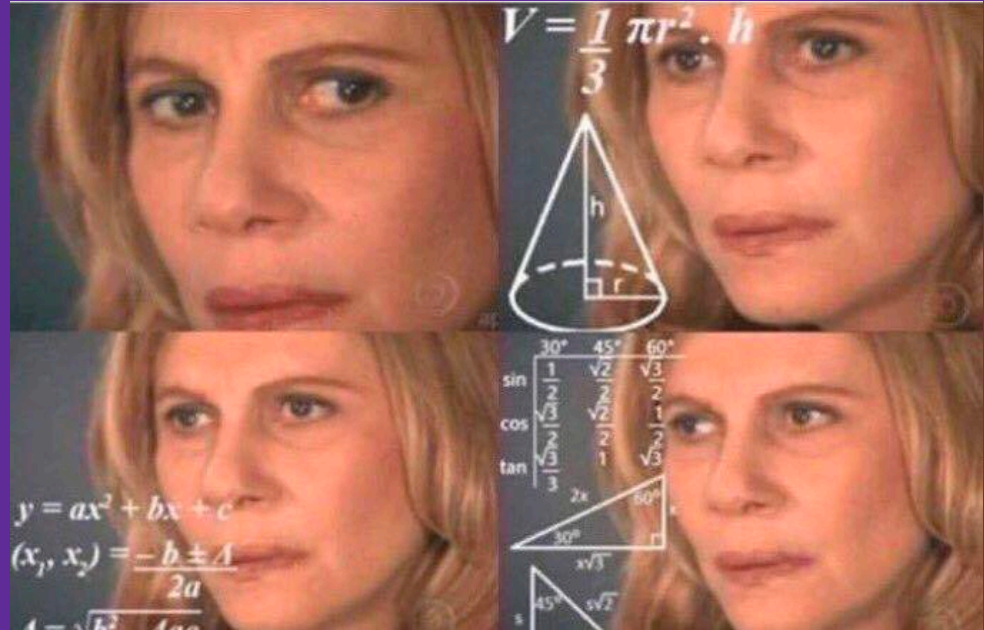


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Systematic Uncertainties!

**Should explain full
catalog of GWs!**

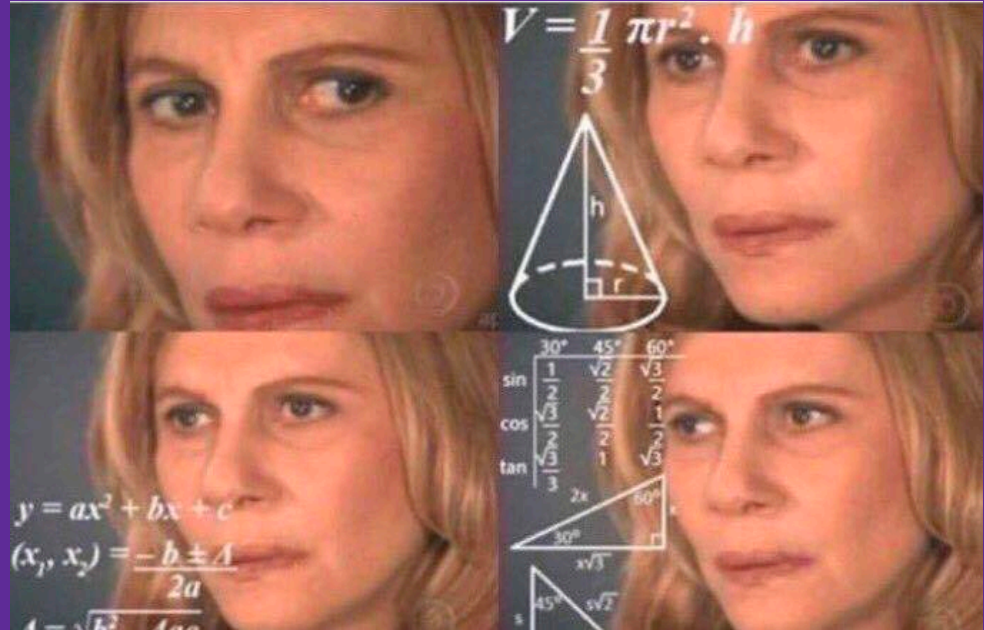


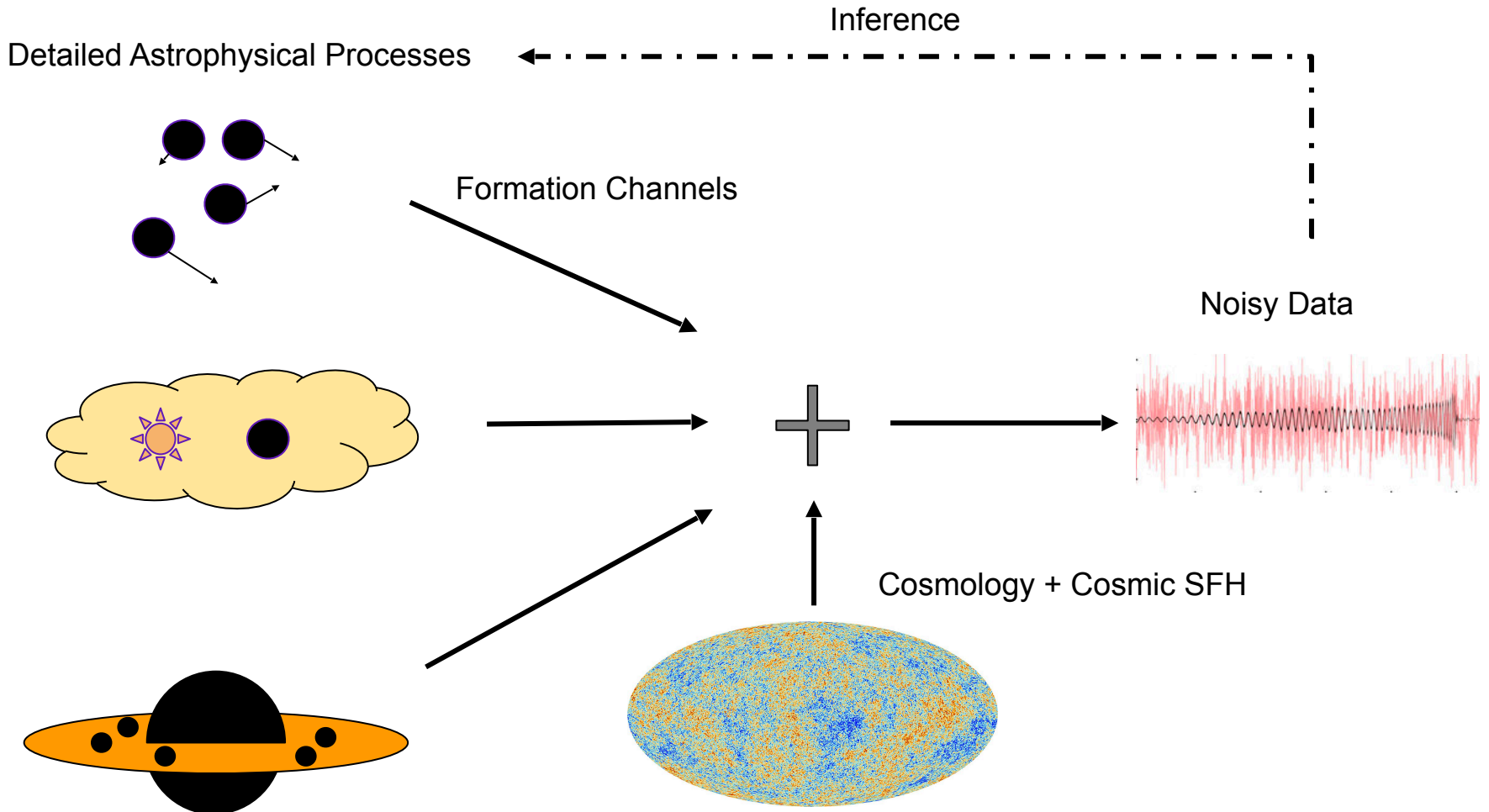
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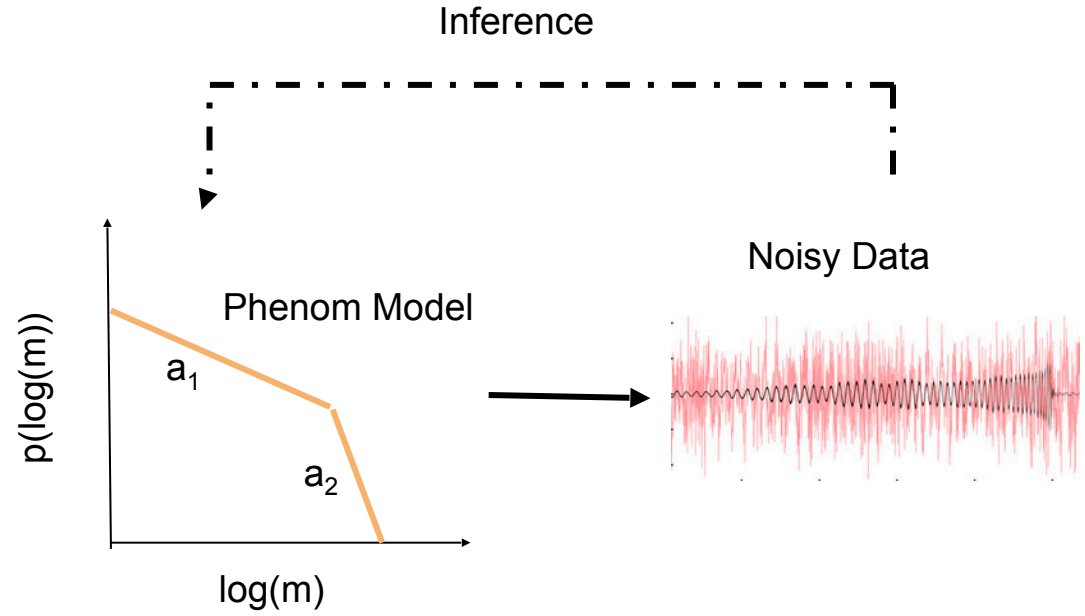
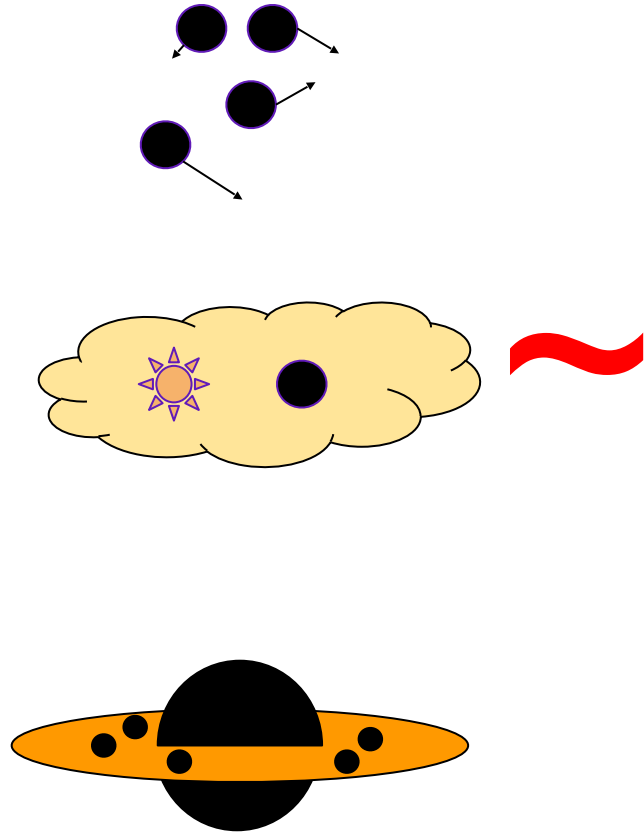
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Detailed Astrophysical Processes



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- Targeted questions (e.g. mass gaps)
- Easy to write down (e.g. power laws)
- Somewhat agnostic to astrophysical details
- Could miss important features

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- Compare with features in detailed models
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SYNERGY!

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Simple Models

Fishbach & Holz (2017)

Talbot & Thrane (2018)

Wysocki, Lange, and O'Shaughnessy (2019)

Doctor et al (2020)

Kimball et al (2021)

Landry & Read (2021)

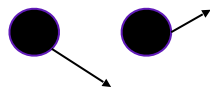
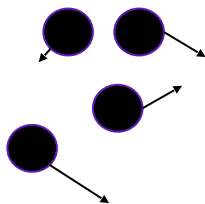
Farah, Fishbach, Essick et al (2021)

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Do BH sub-populations of spin have different masses?

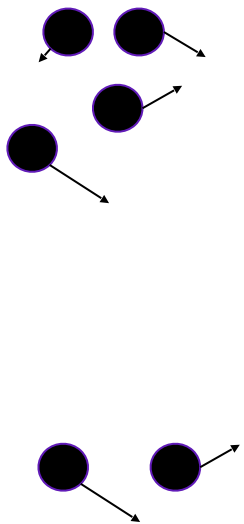
Do BH sub-populations of spin have different masses?

Dynamical
Channel

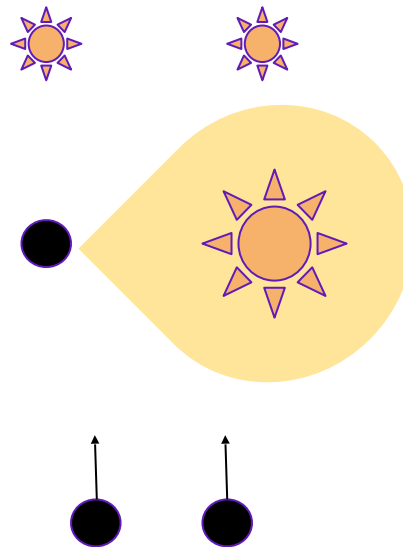


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Isolated Binary
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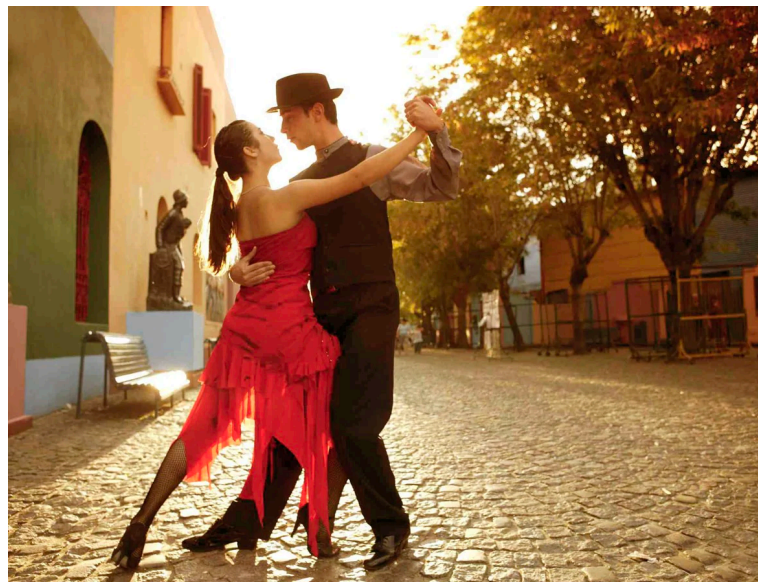


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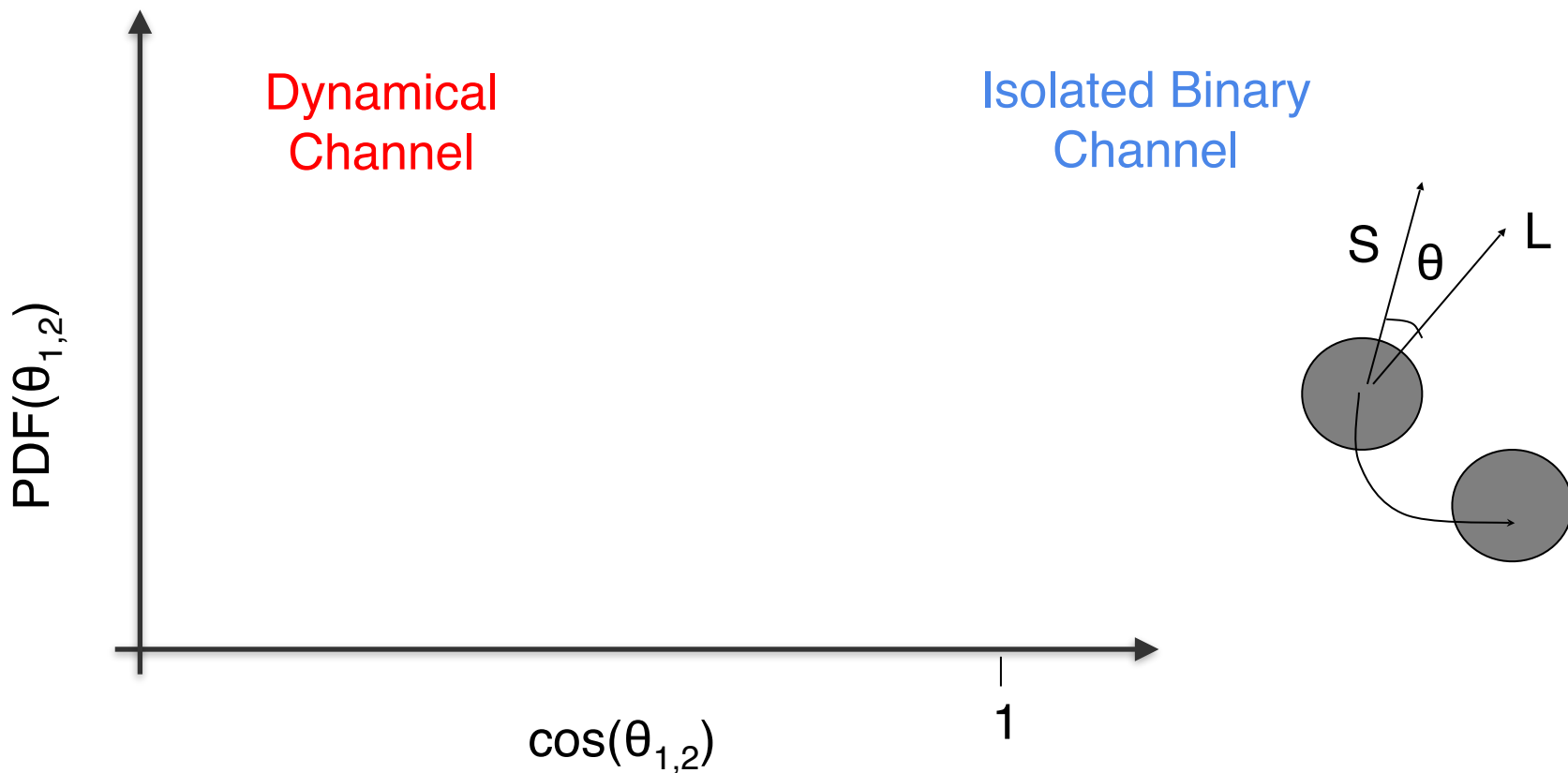
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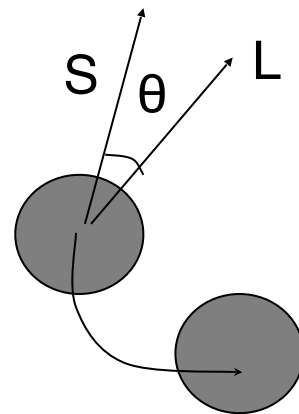
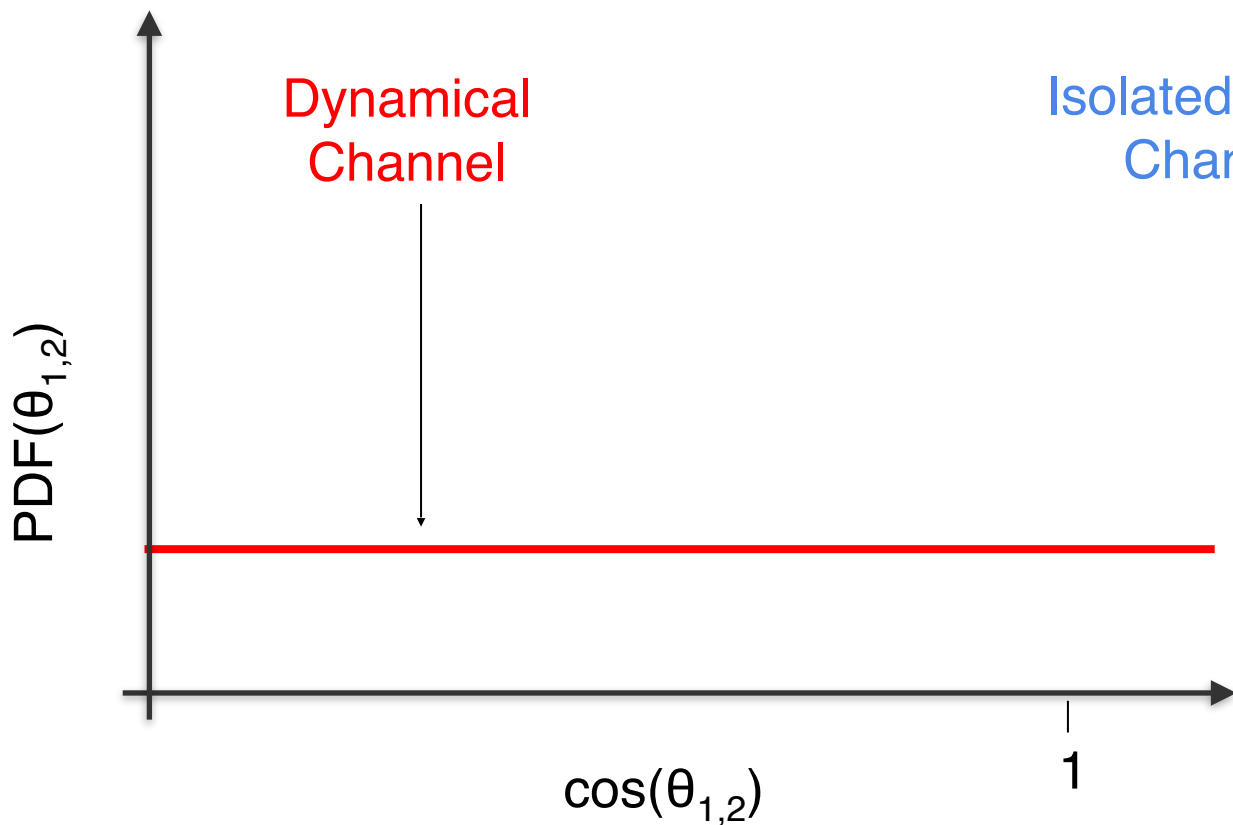
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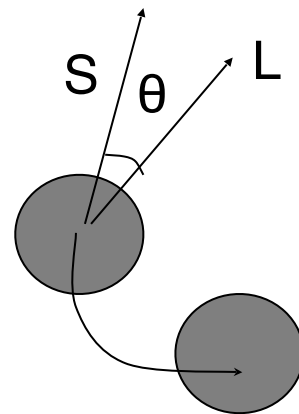
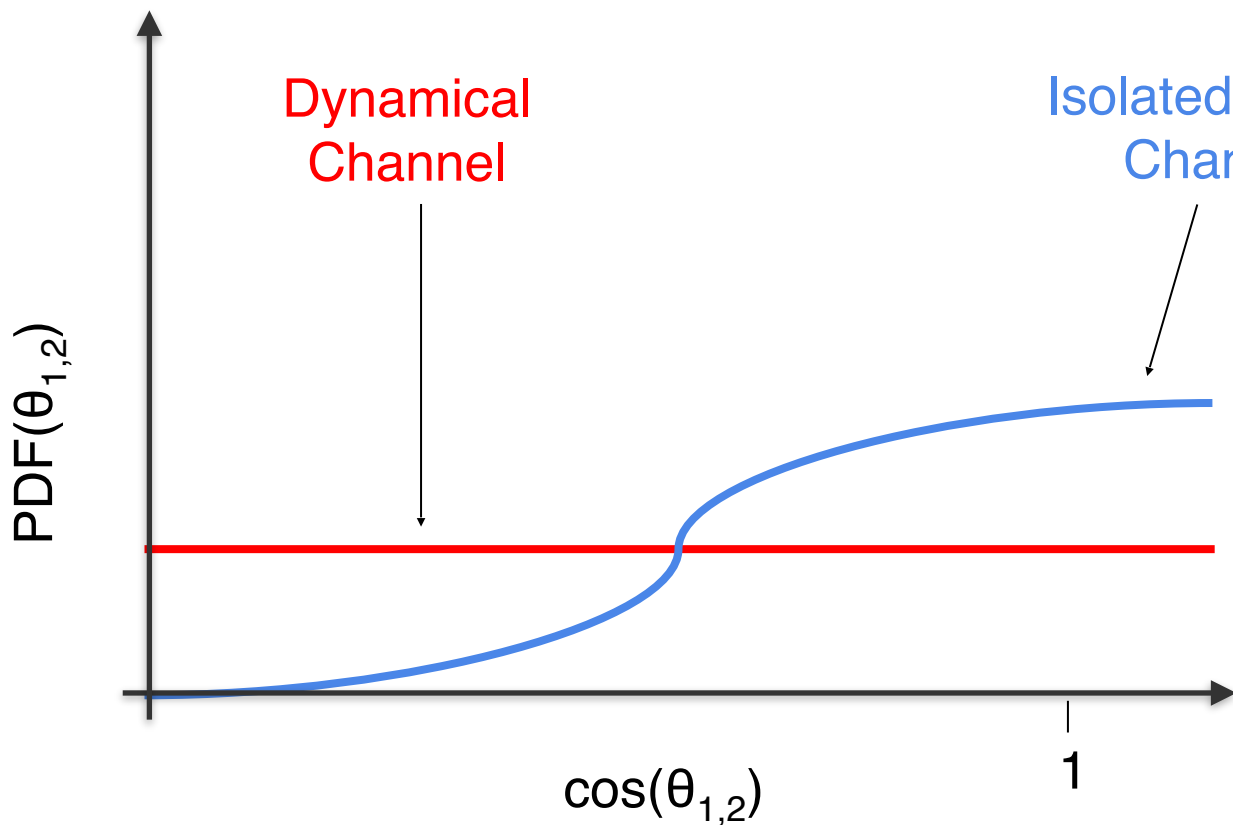
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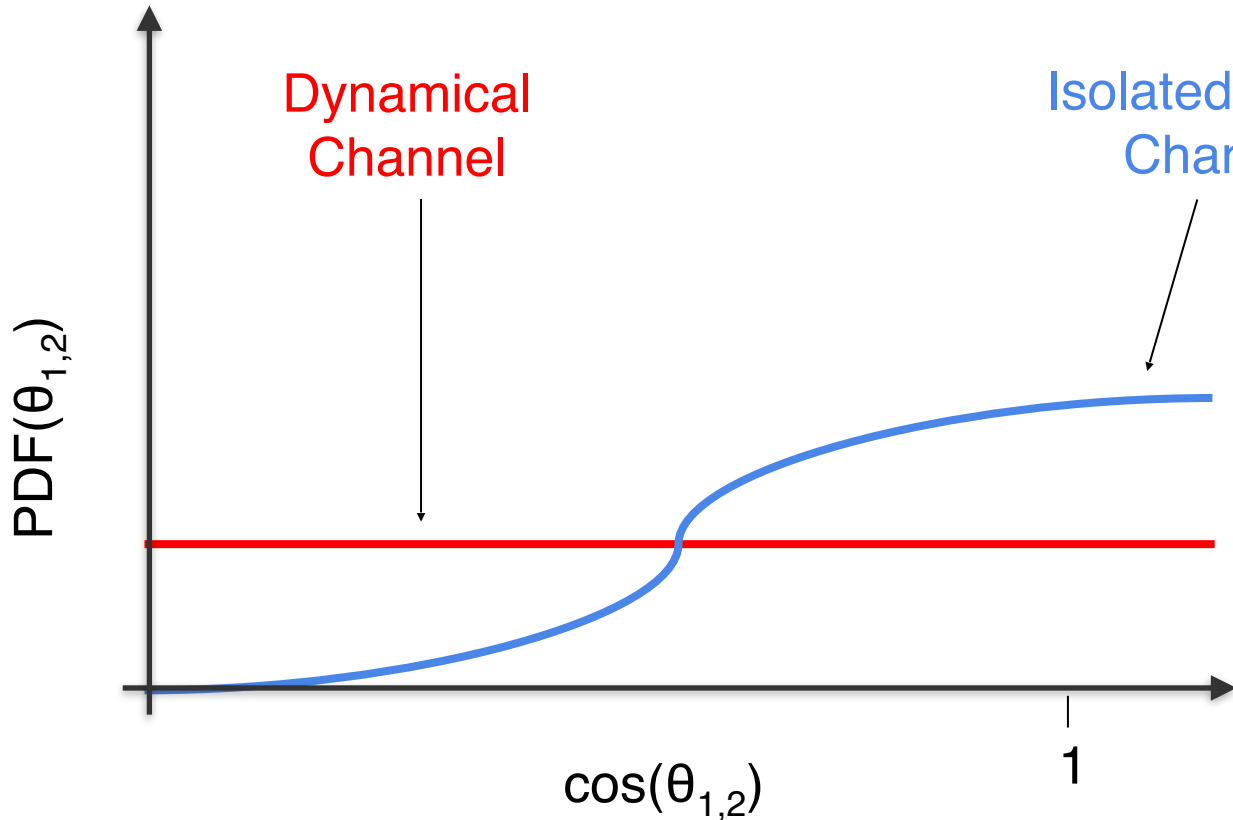
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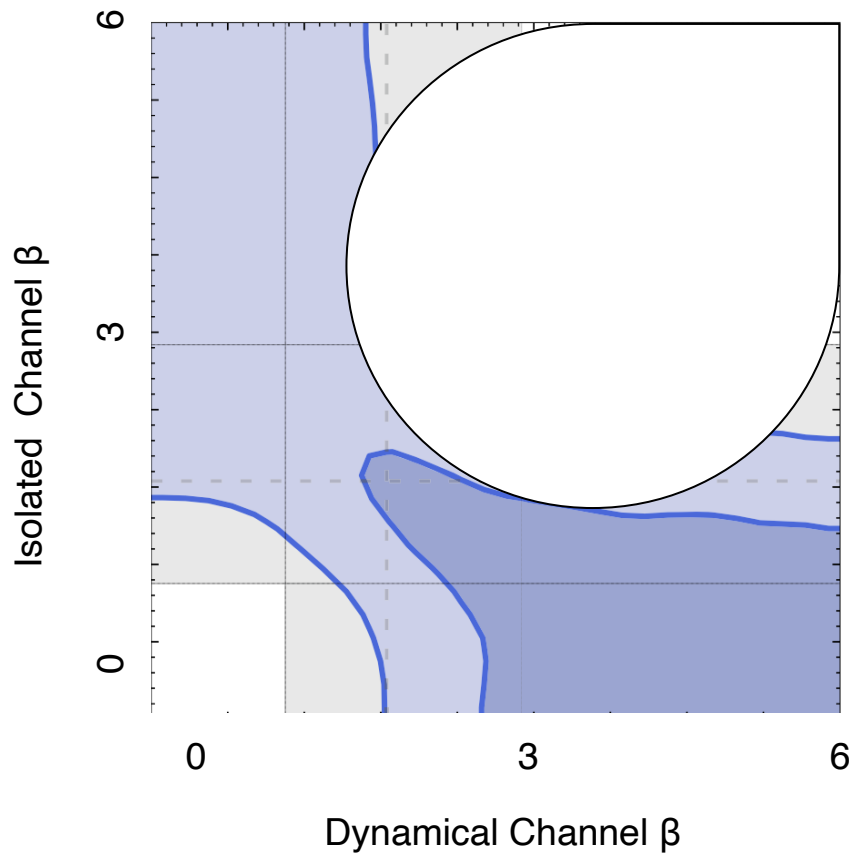


Do BH sub-populations of spin have different masses?



Do these putative sub-populations have different mass-ratio distributions?

Do BH sub-populations of spin have different masses?

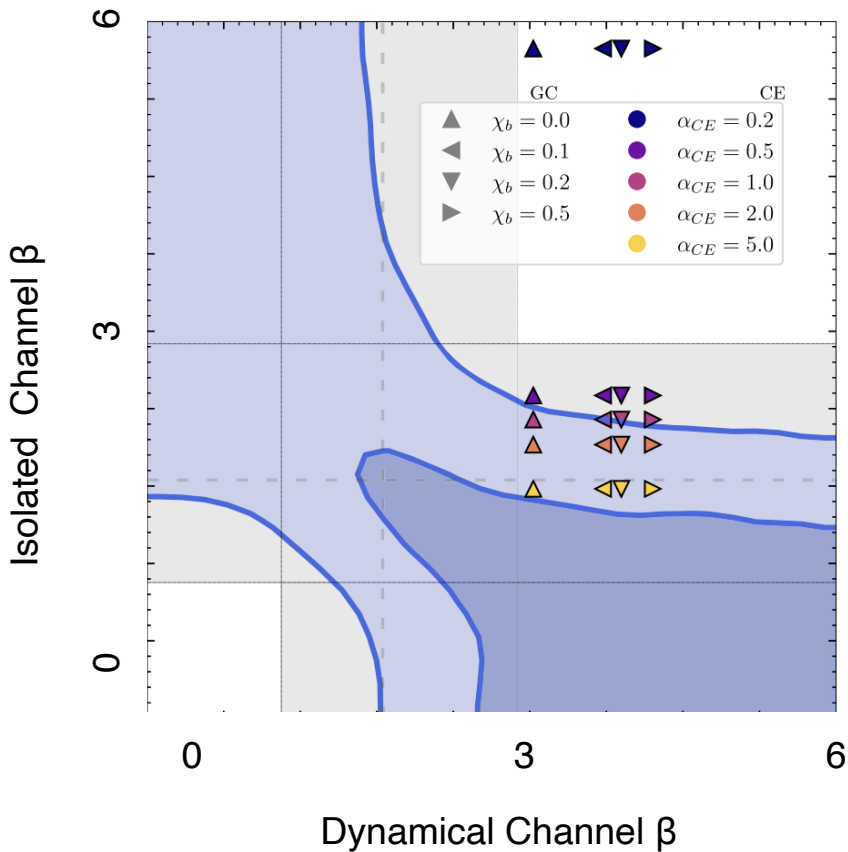


$$p(q) \sim q^\beta$$



CIERA Fellow
Vishal Baibhav

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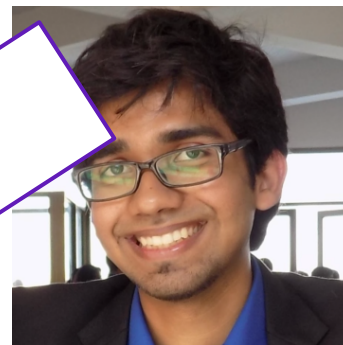
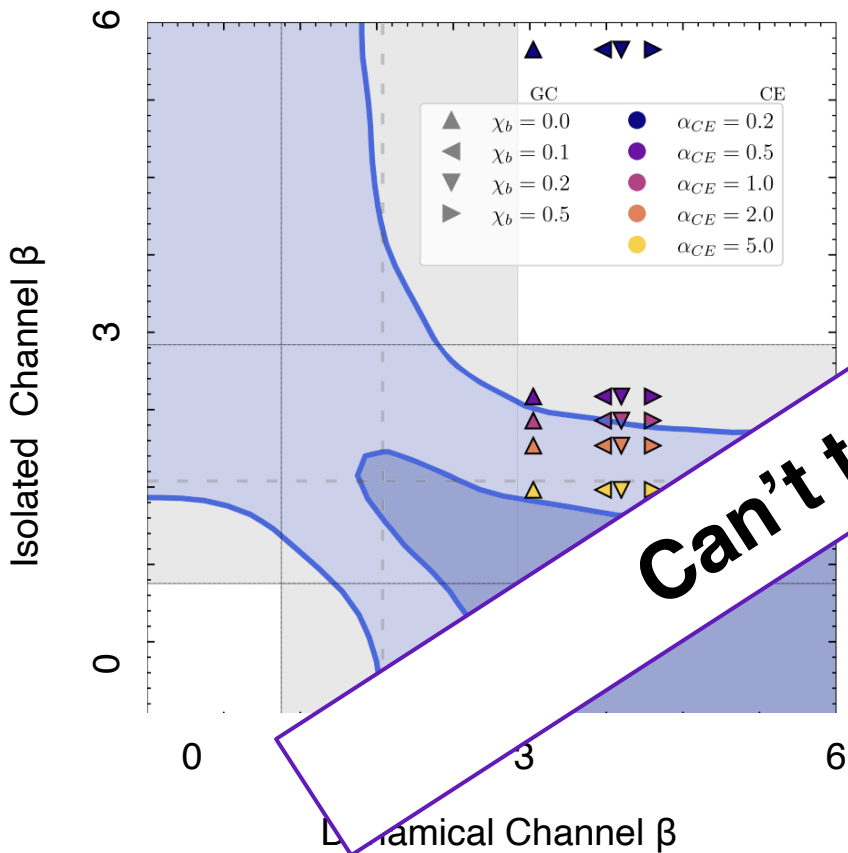


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Data-Driven Models

Mandel et al (2016)

Farr et al (2018)

Powell et al (2019)

Tiwari (2021)

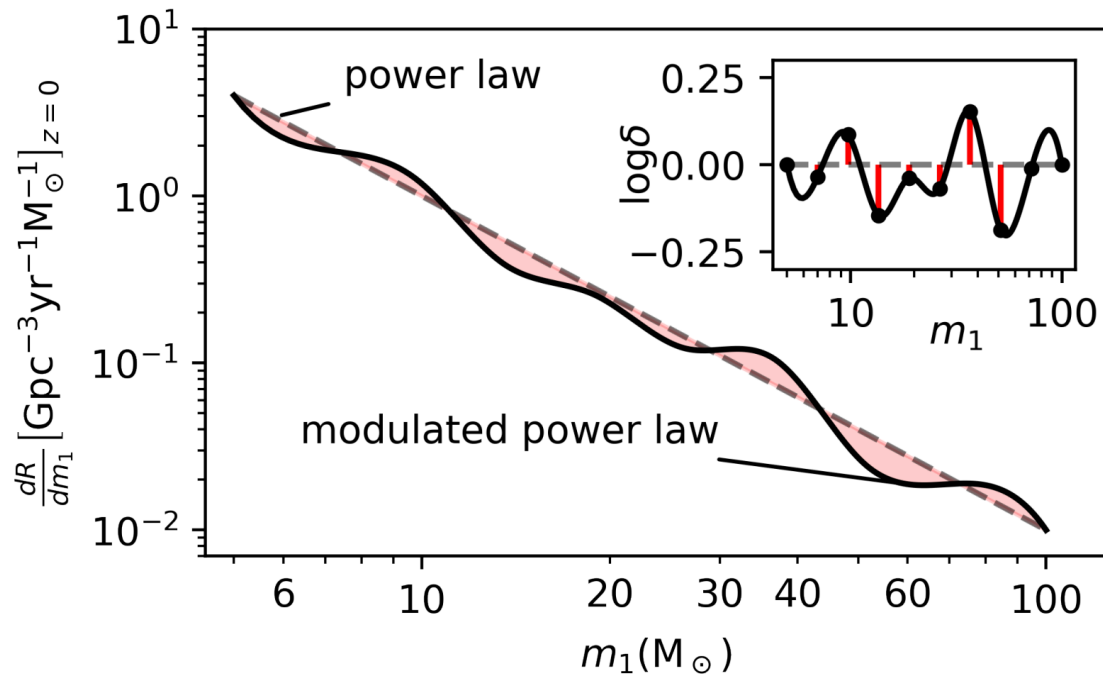
Rinaldi et al (2021)

Sadiq et al (2021)

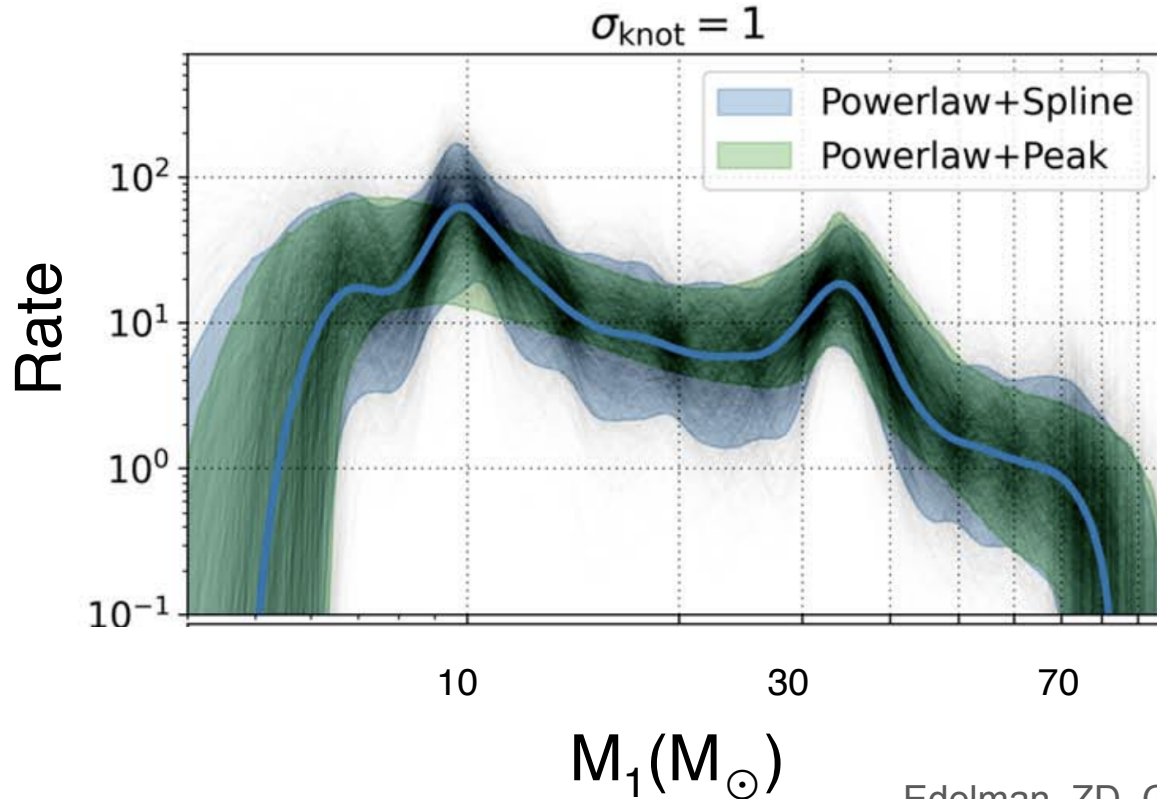
Godfrey et al (2023)

...

Is there structure in the BBH mass distribution?

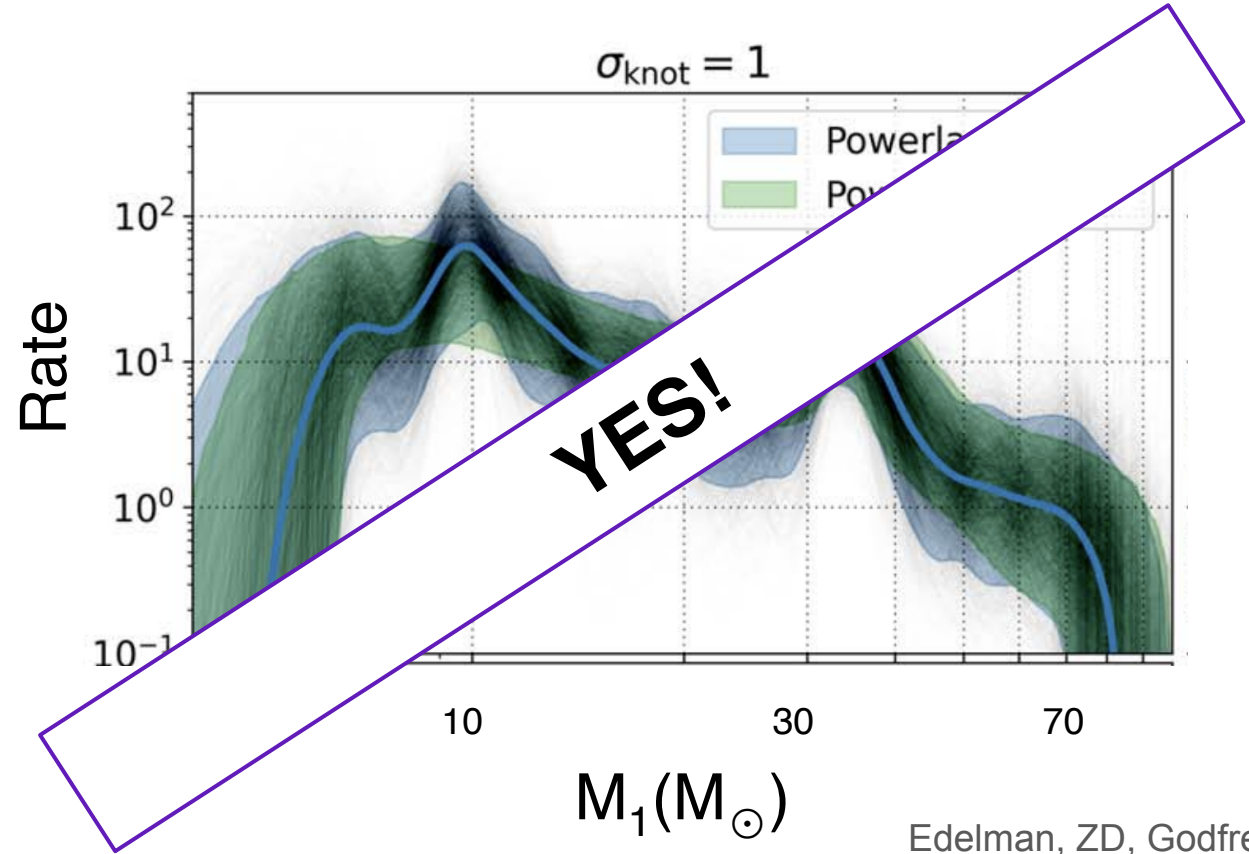


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Bruce Edelman
UO Grad

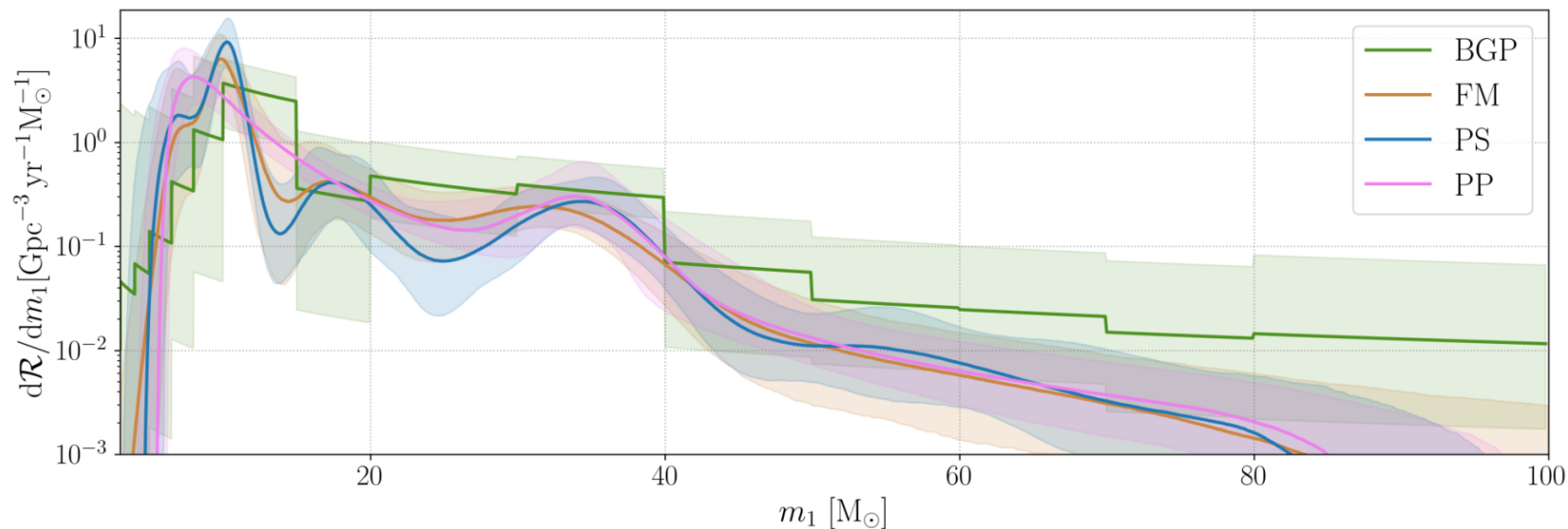
Is there structure in the BBH mass distribution?



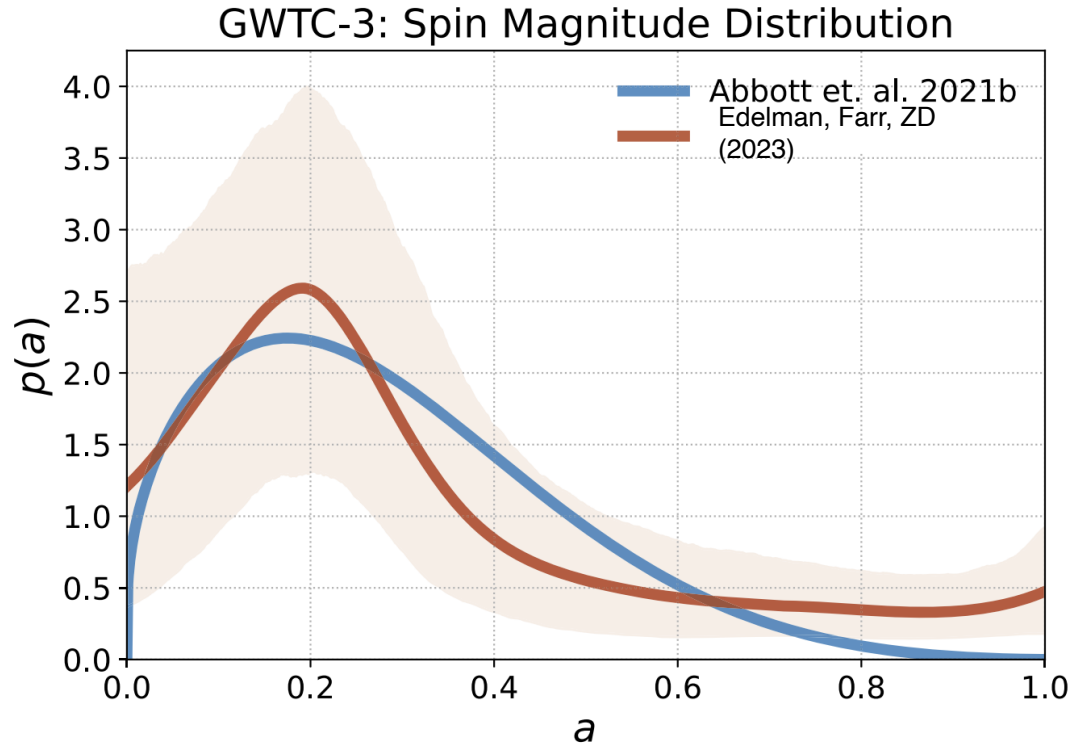
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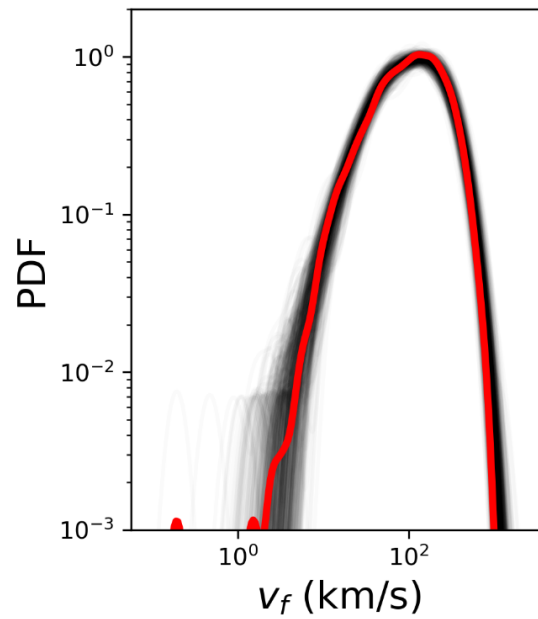
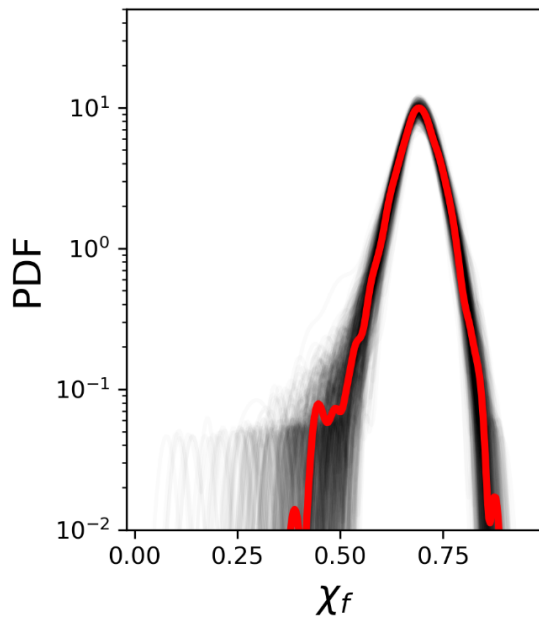
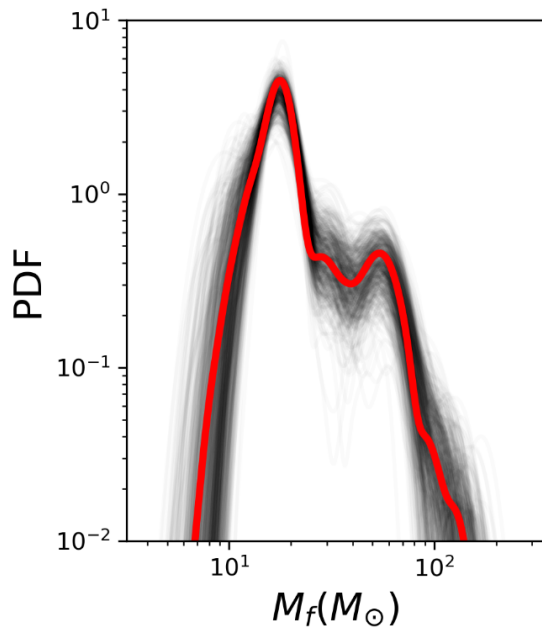
Other approaches find the same result



Is there structure in the BBH **spin** distribution?



What are the properties of BBH merger remnants?

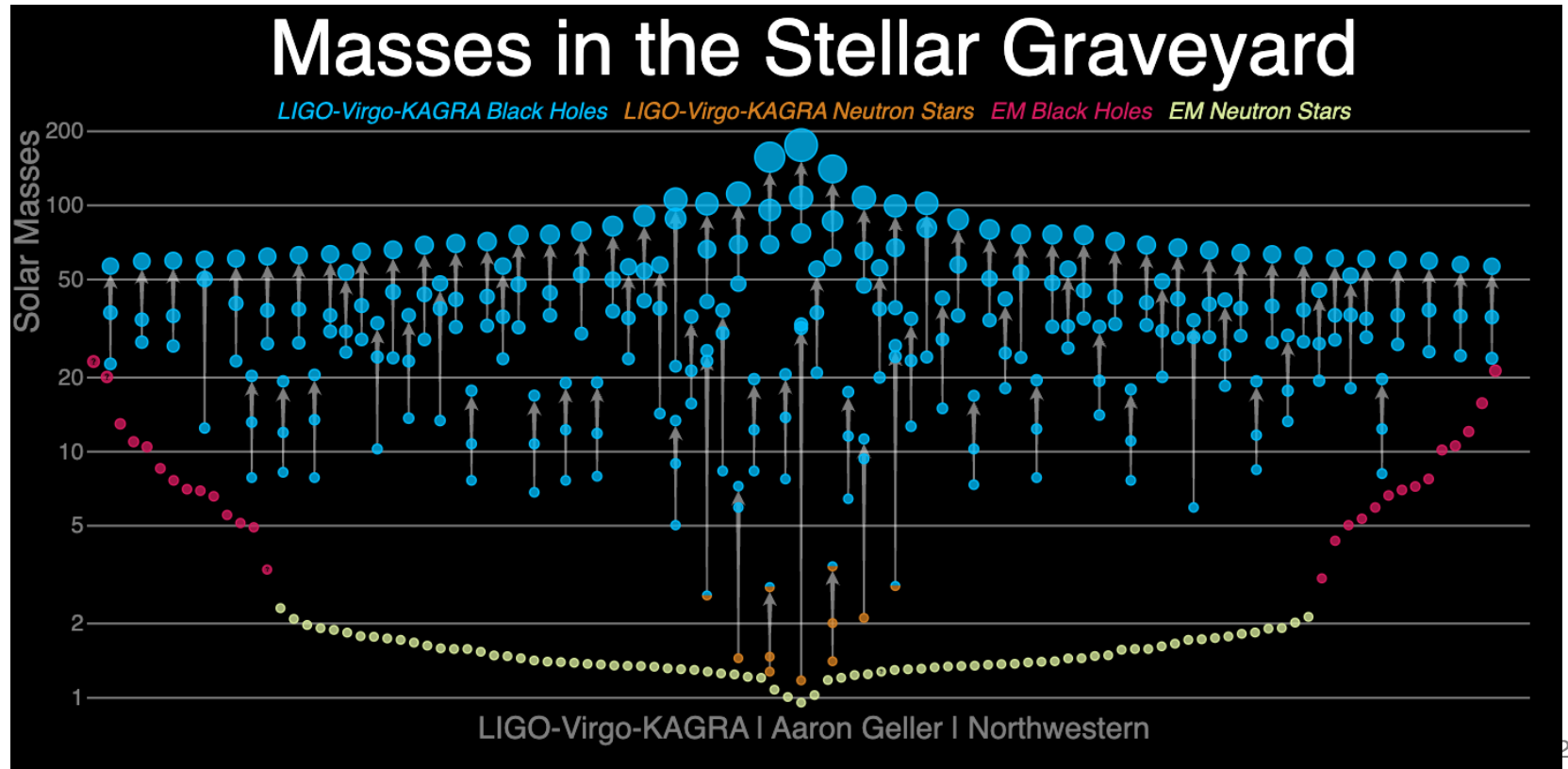


Detailed Models

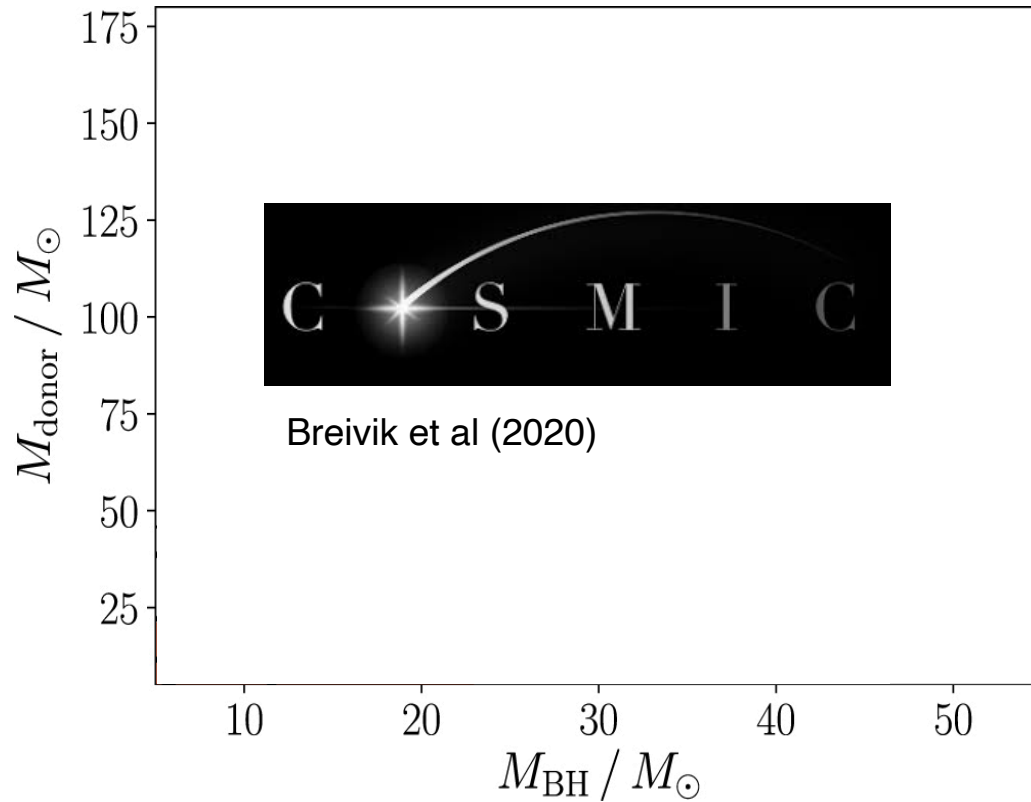
BPASS
BSE
CMC
ComBinE
COMPAS
COSMIC
MOBSE
POSYDON
SEVN
StarTrack ...

How do merging BH masses compare to those in HMXBs?

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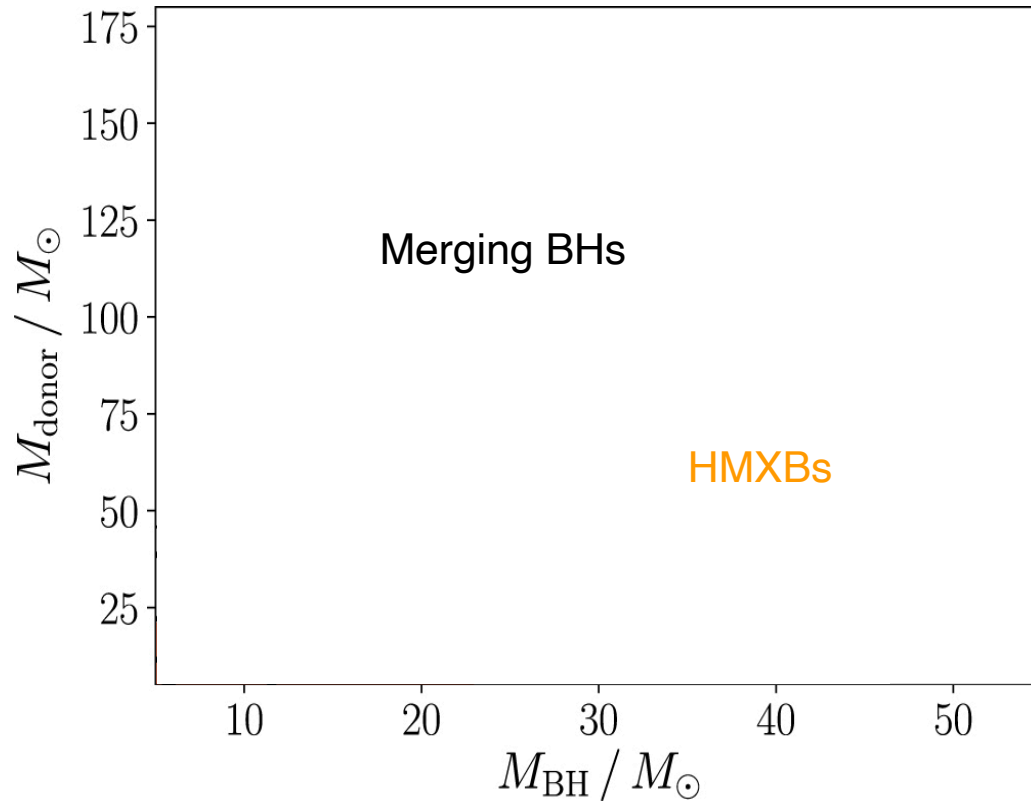


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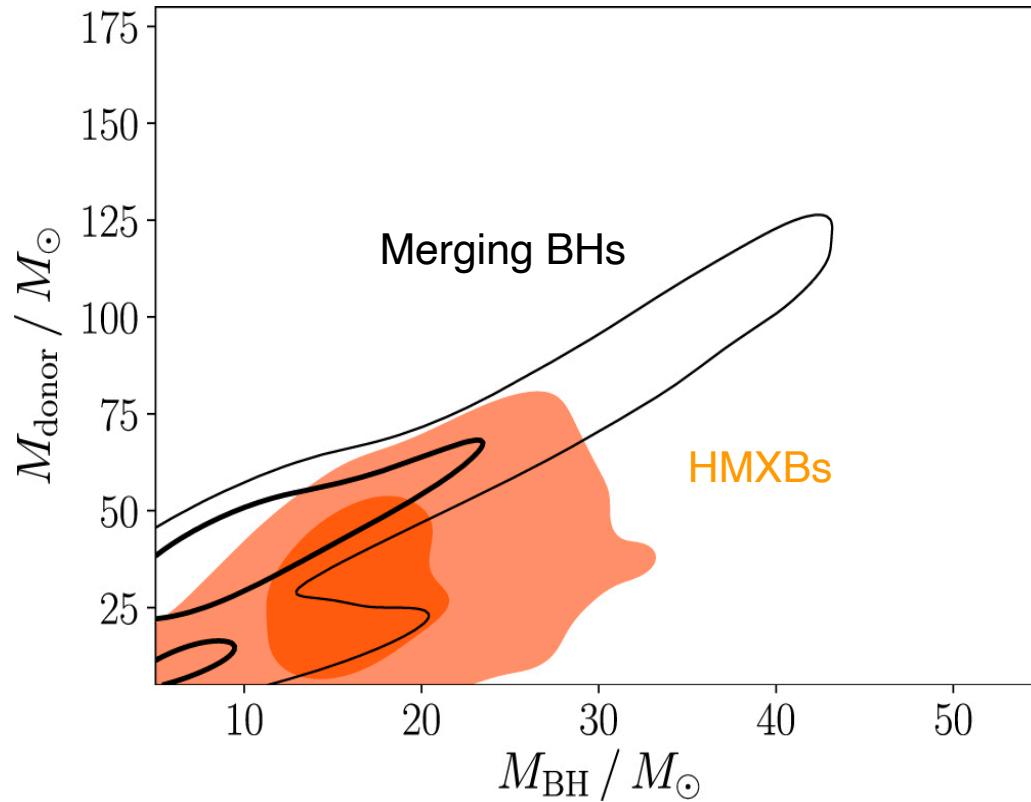
Camille
Liotine
(CIERA grad)

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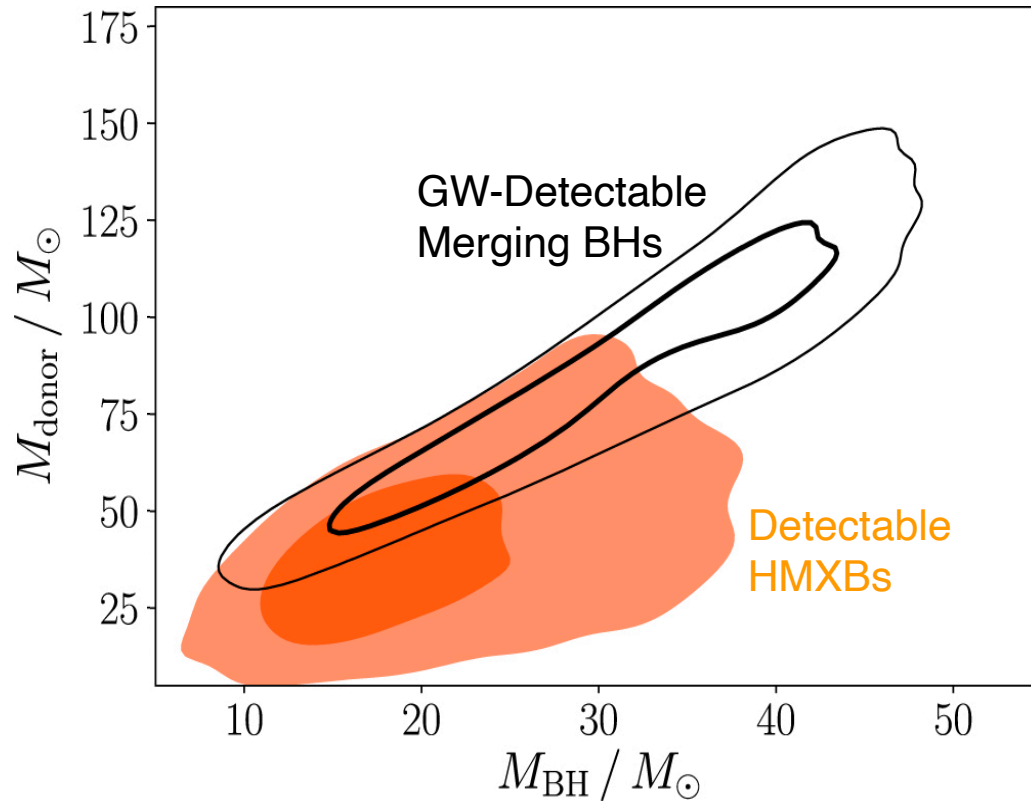
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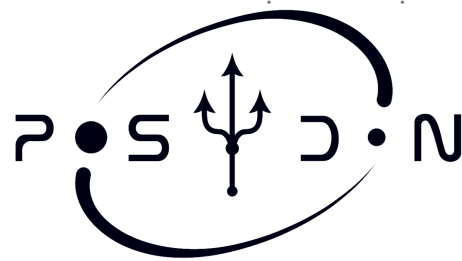
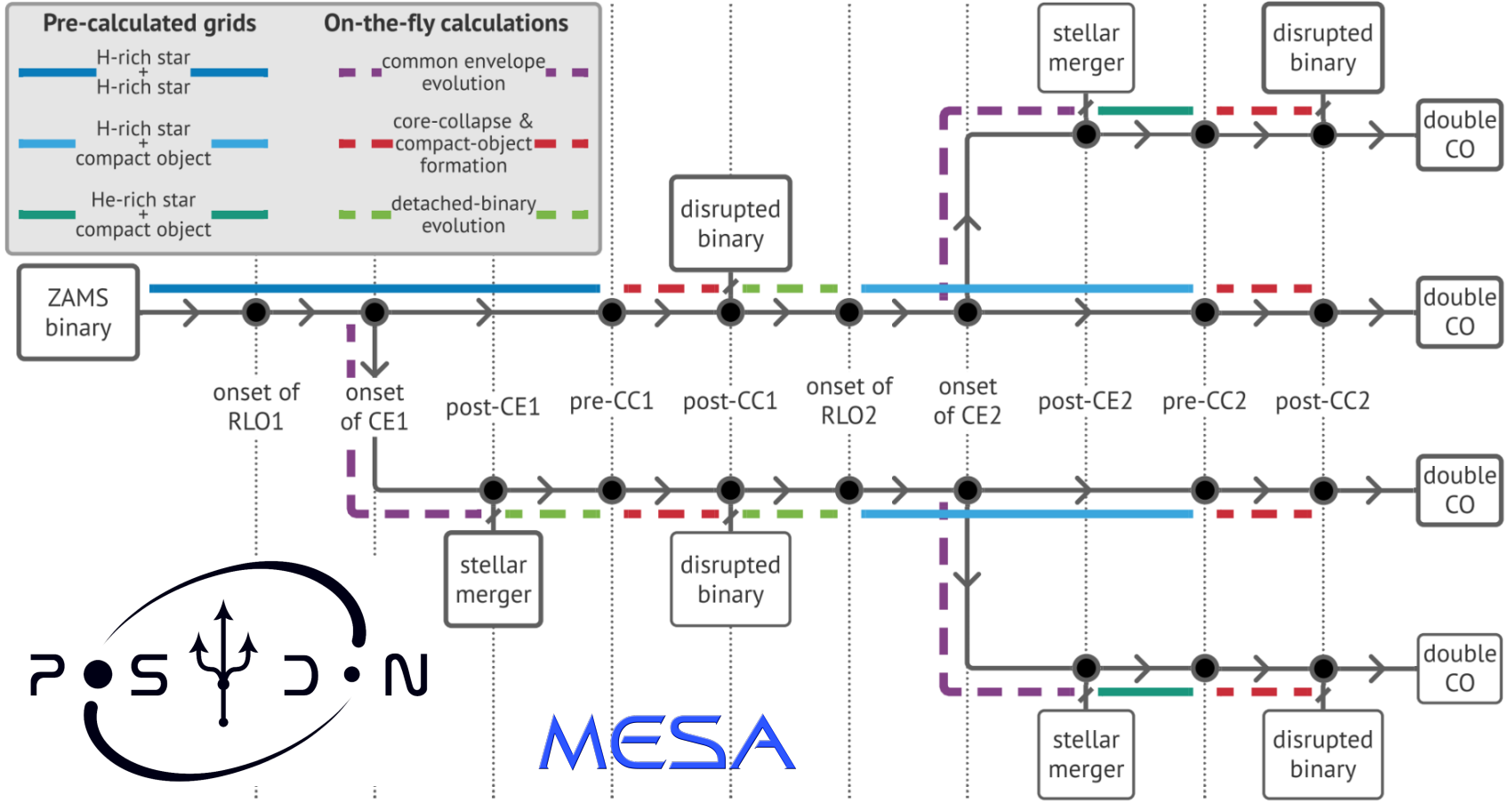
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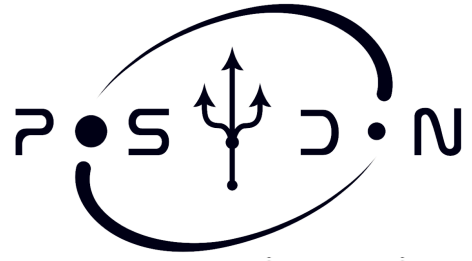
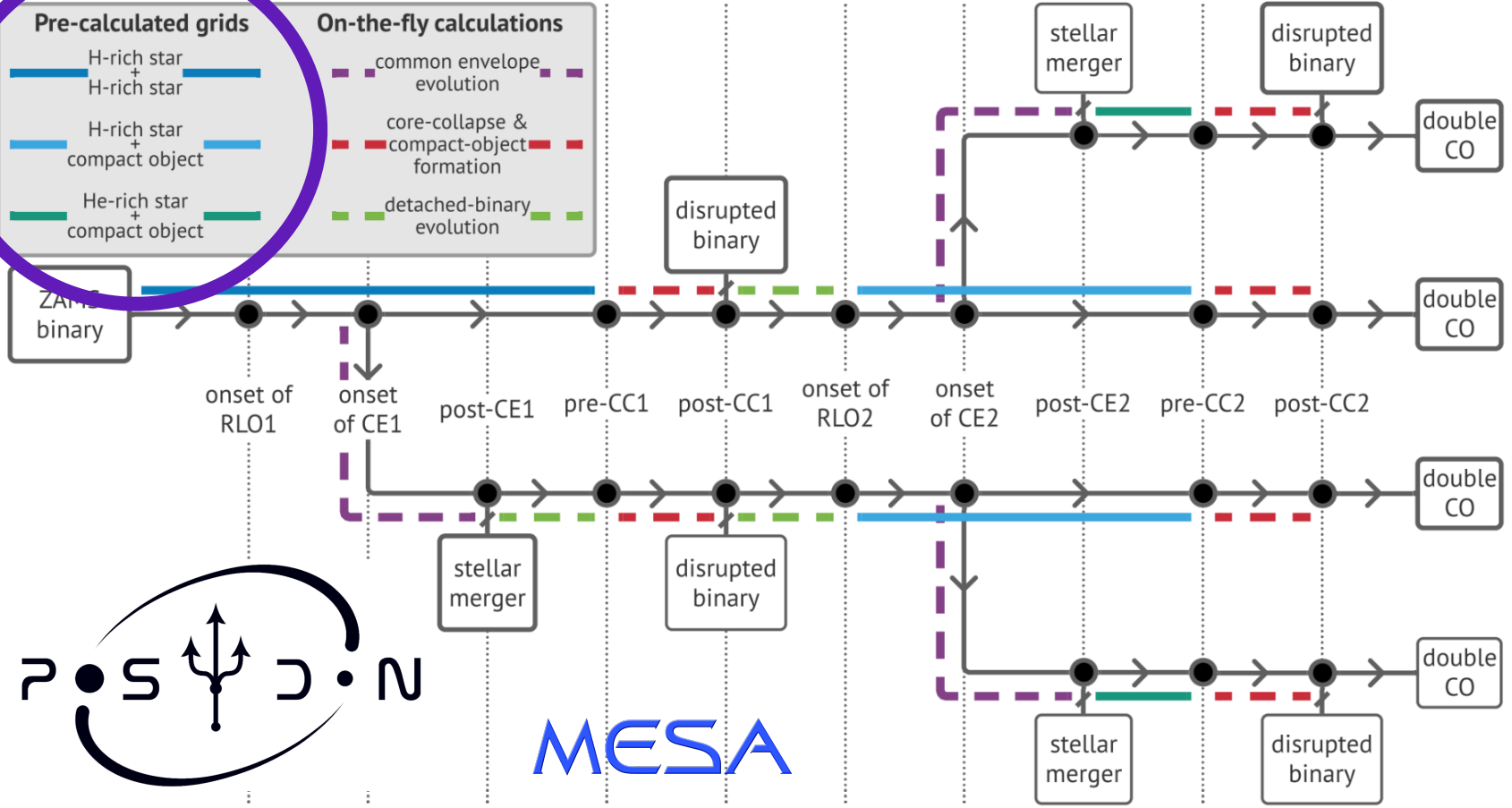
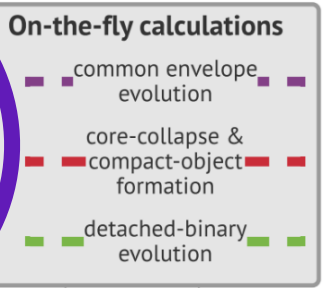
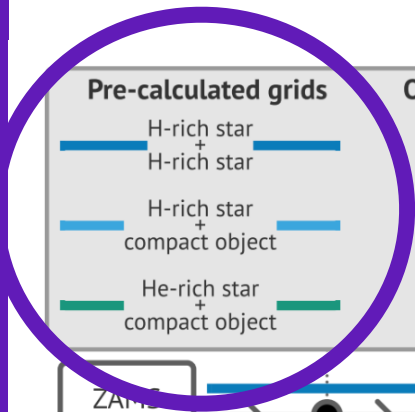
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- Probability detected HMXB will merge as a BBH in a Hubble time is $\approx 1\%$
- Discrepant BH masses from GWs and HMXBs are expected!



Fragos et al (2022)



Paxton et al (2011)



Fragos et al (2022)



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Remarks

- Multiple population modeling approaches enable us to understand CO mergers from different angles
- There should be concordance between GWs and other observables
- Detailed models: Incorporate our full astrophysical picture, but expensive and many systematics
- Simple parametric models: Empirically test specific questions
- Data-driven models: Look for the unexpected, black box predictions for other observables

**IF YOU COULD, JUST SEND US MORE
GRAVITATIONAL WAVES**

THAT'D BE GREAT

