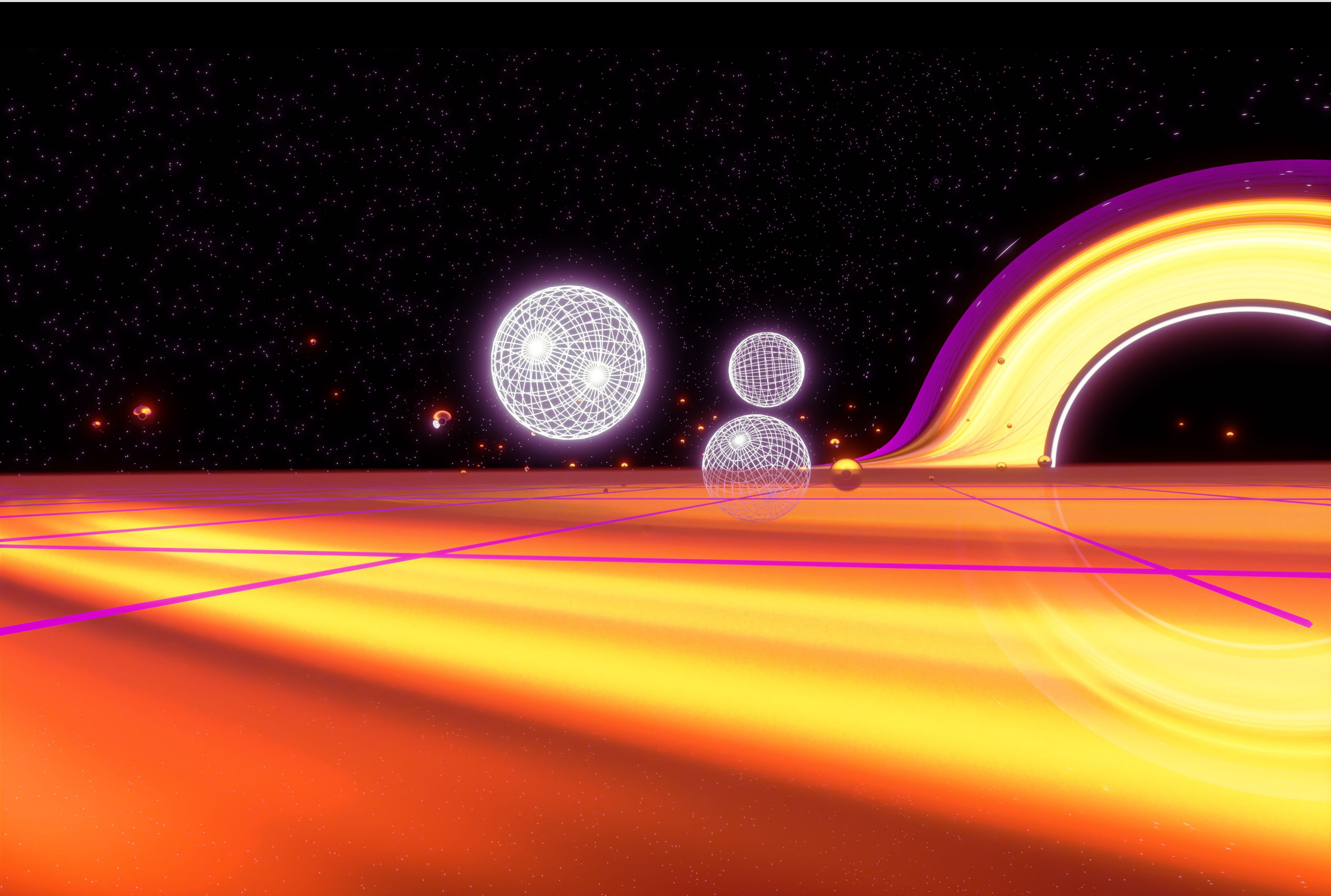
Gravitational Astrophysics

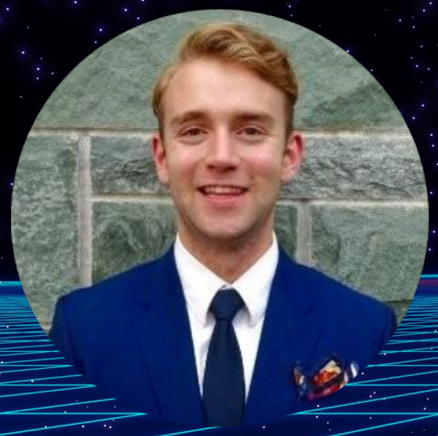


Members

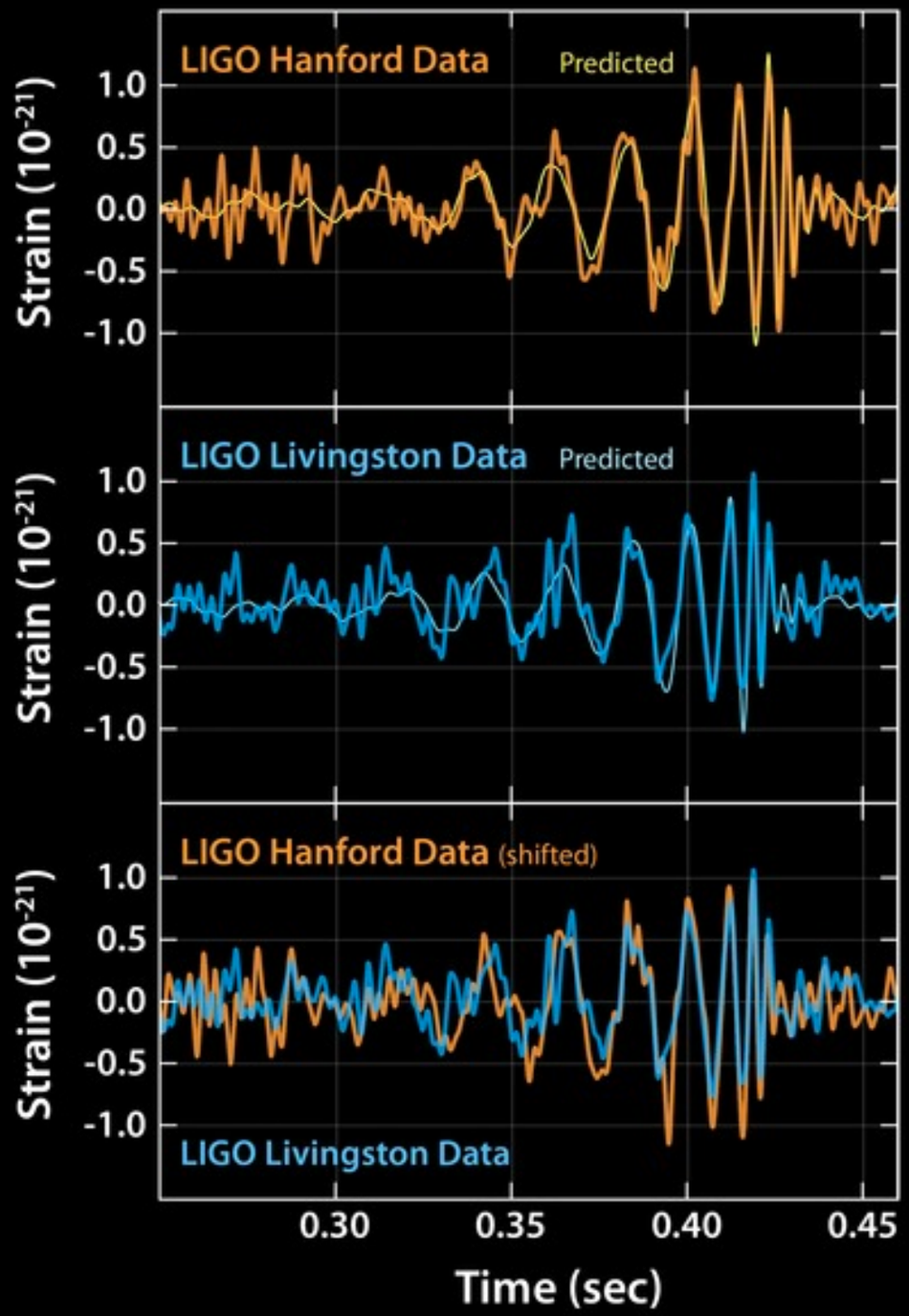
Current MSc Students:

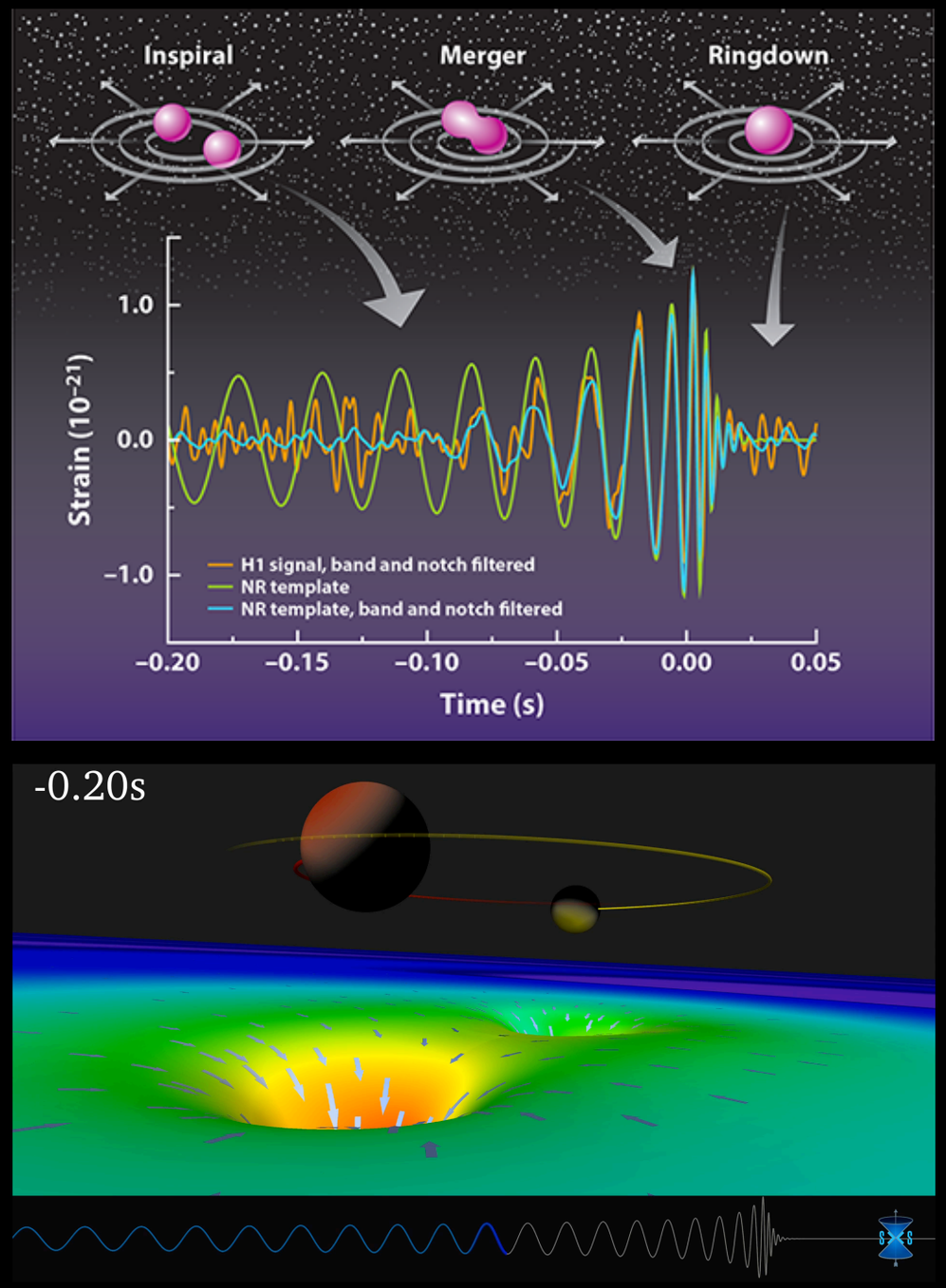
Philip Kirkeberg

Yan Yu

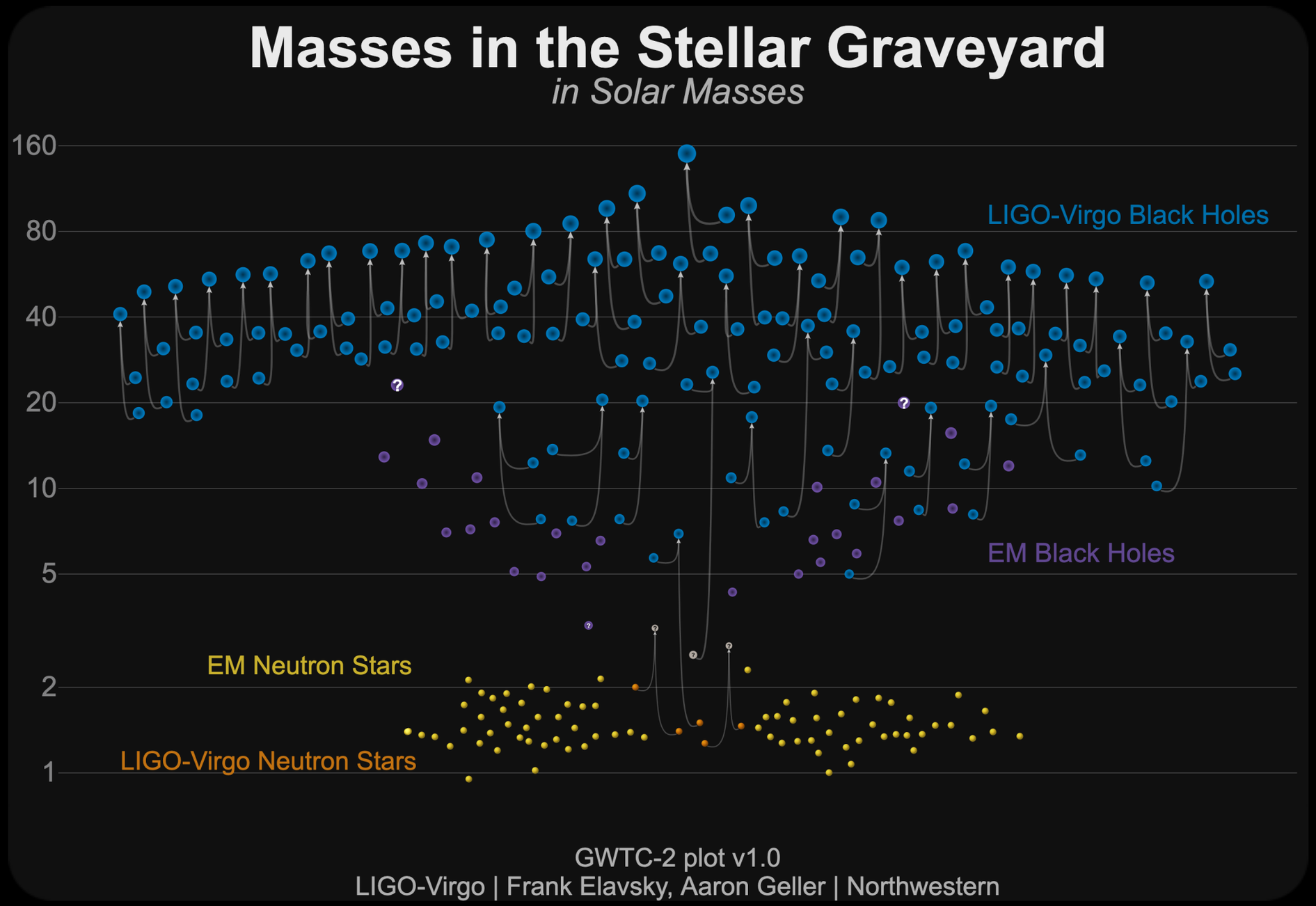


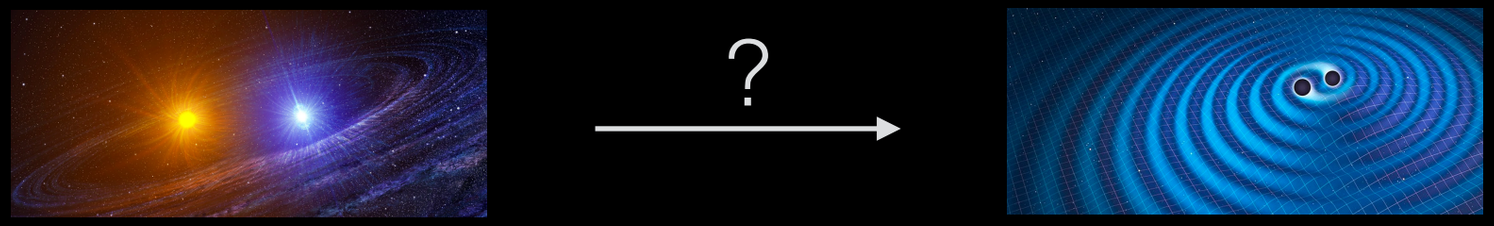
Gravitational Wave Astrophysics





Gravitational Wave Astrophysics



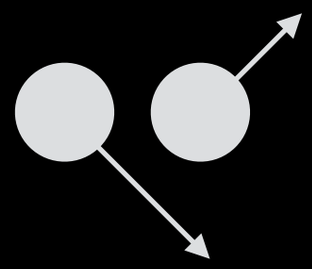


Gravitational Wave Astrophysics

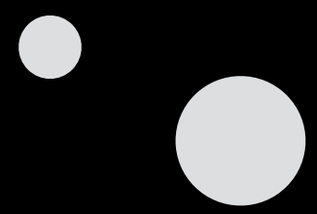
Gravitational Wave Data

Observables

*Black hole **spin***



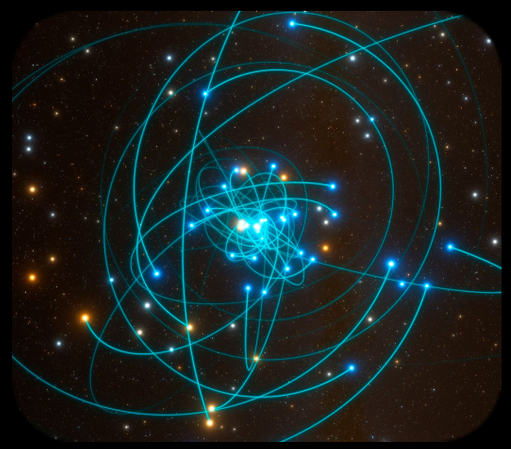
*Black hole **masses***



*Orbital **eccentricity***

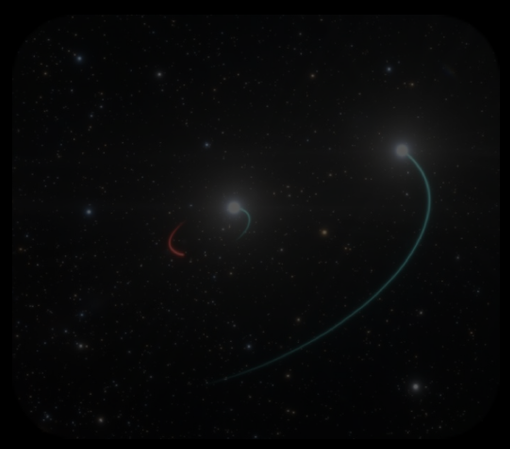
Gravitational Wave Astrophysics

Galactic Center?



Stellar Clusters?

Stellar multiples?



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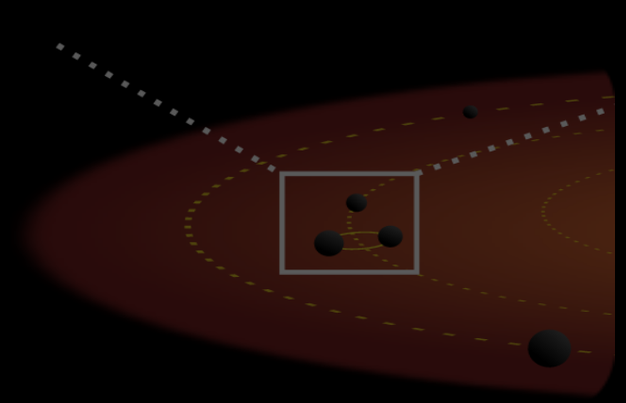

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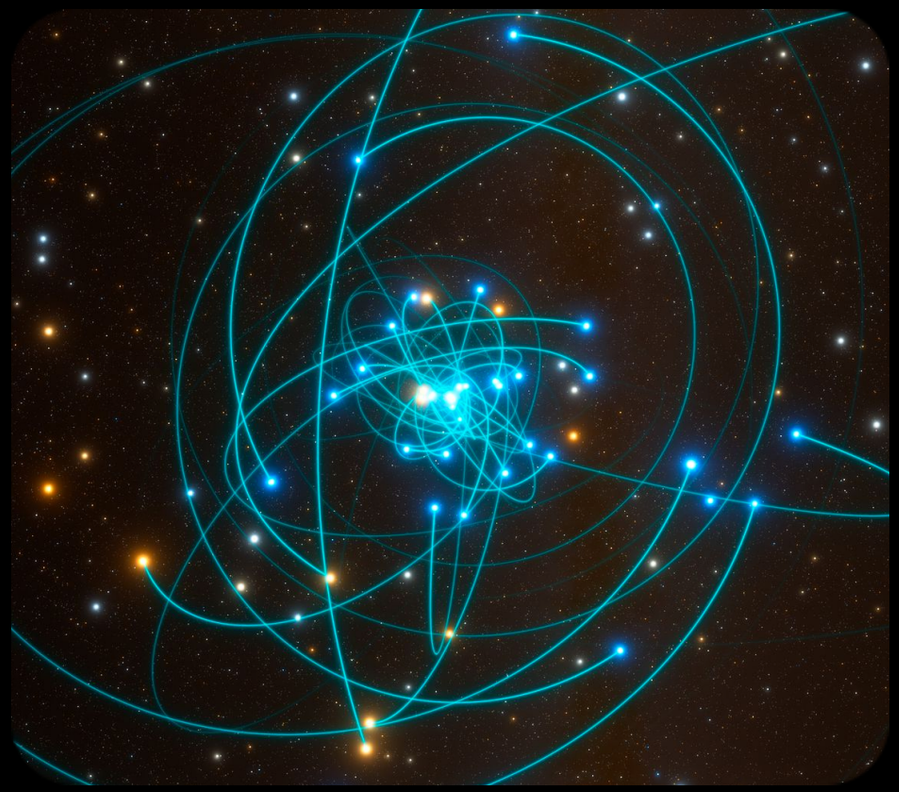

Gravitational Wave Astrophysics

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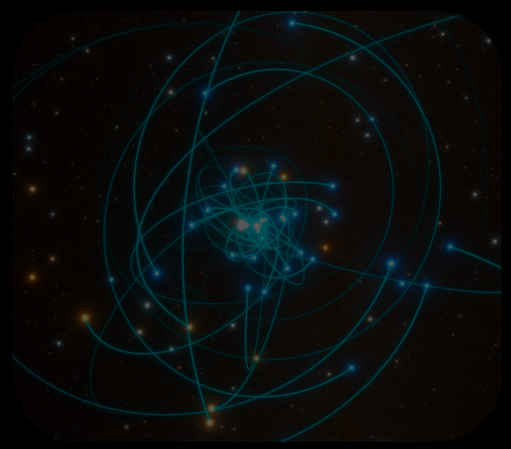

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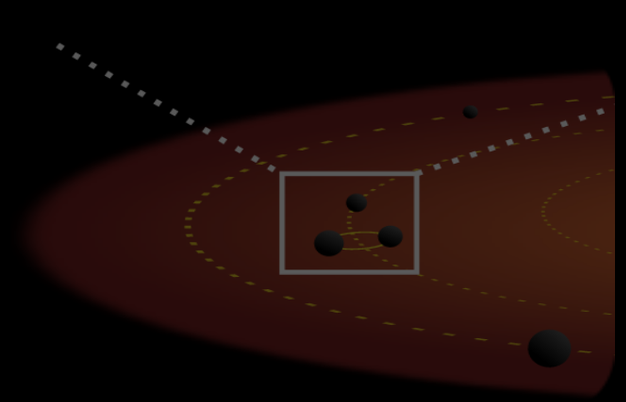
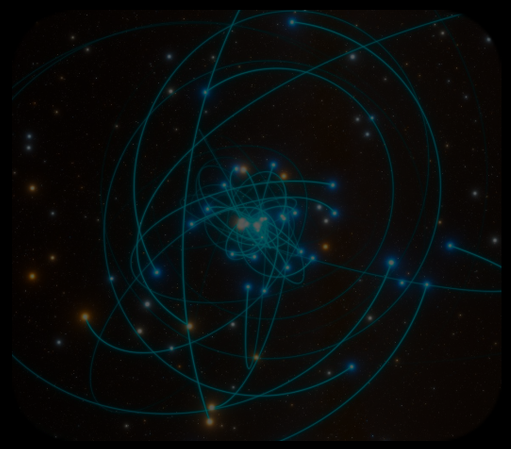


Stellar Clusters?

Gravitational Wave Astrophysics

Galactic Center?



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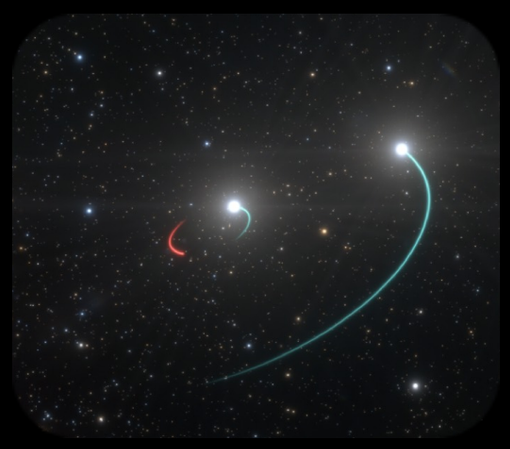

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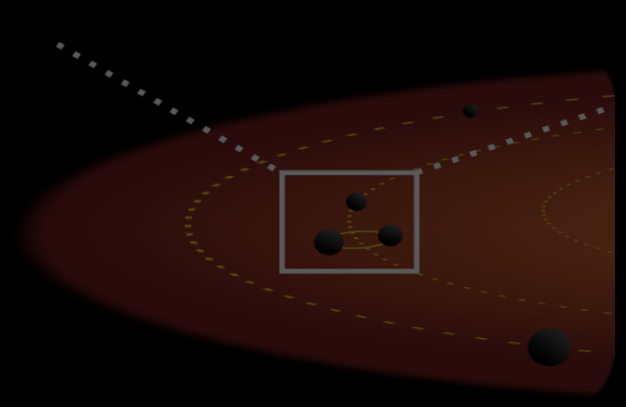
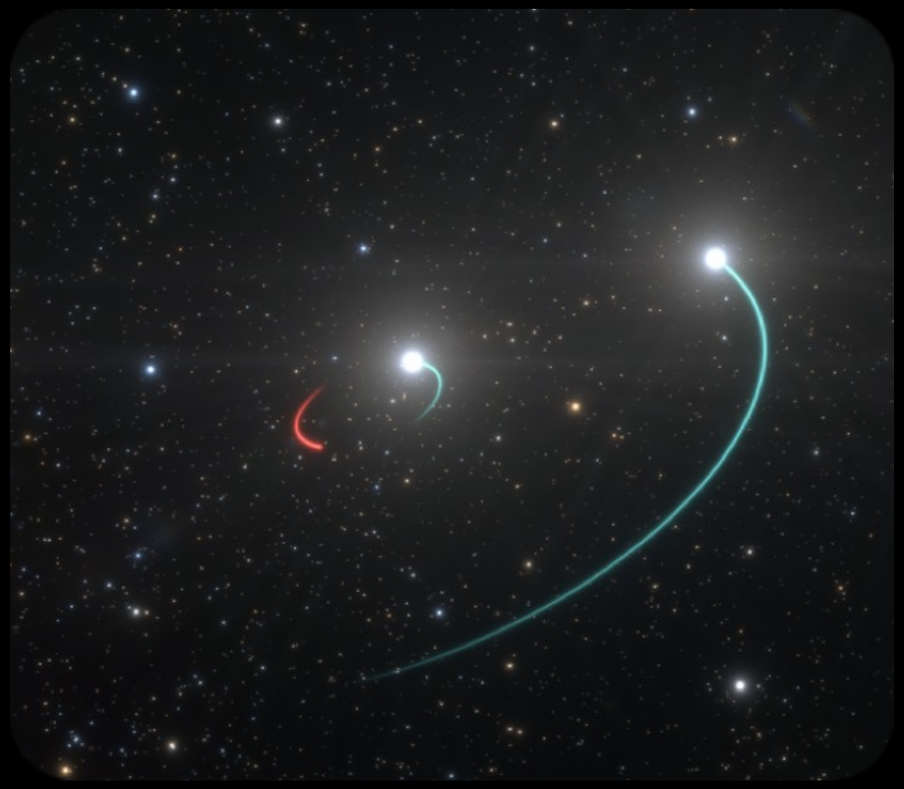
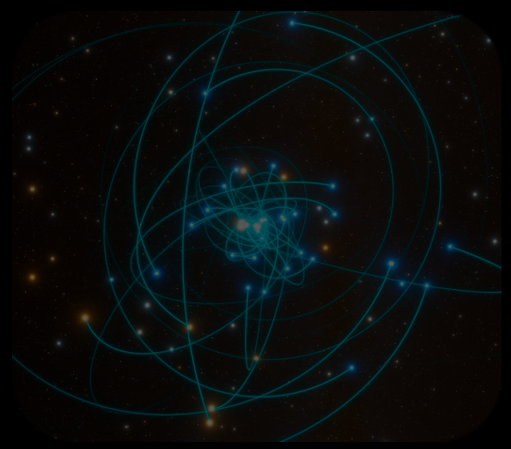


Stellar multiples?



Gravitational Wave Astrophysics

Galactic Center?



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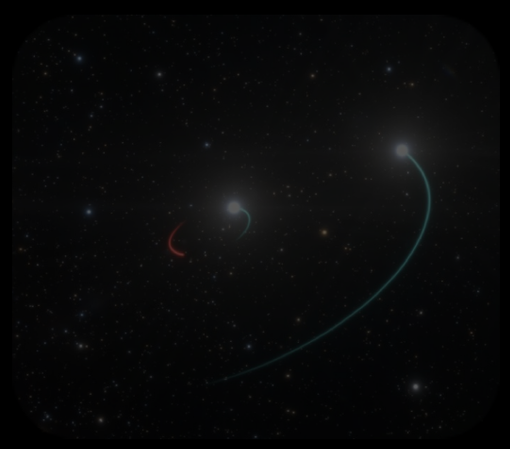

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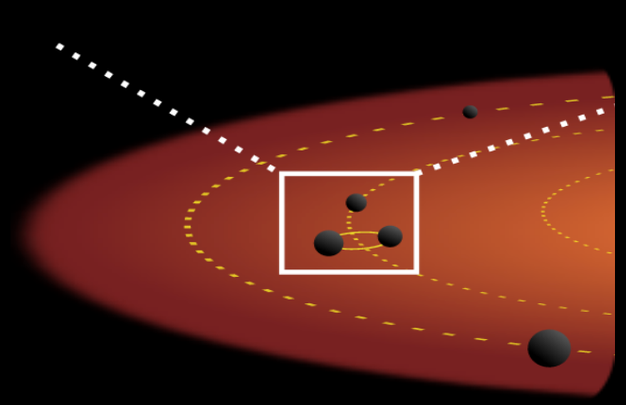

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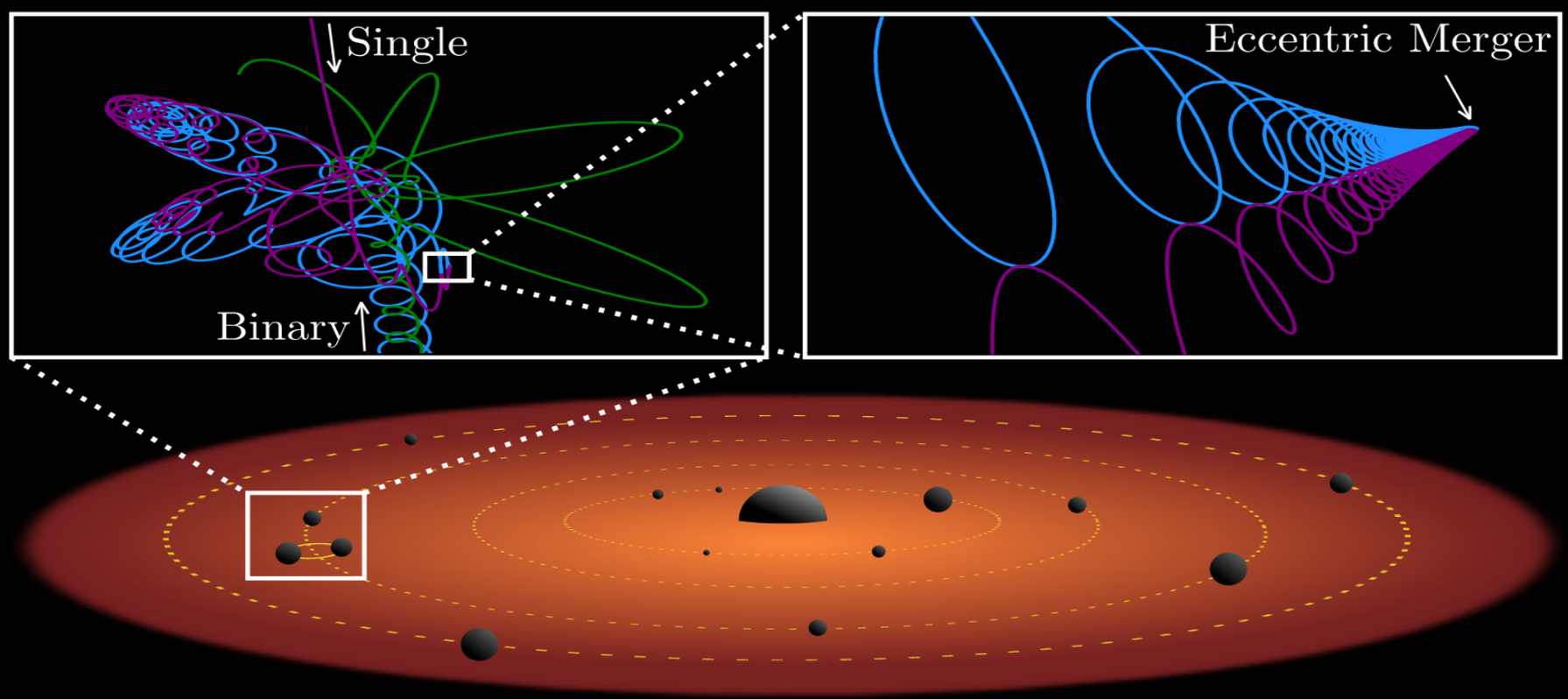
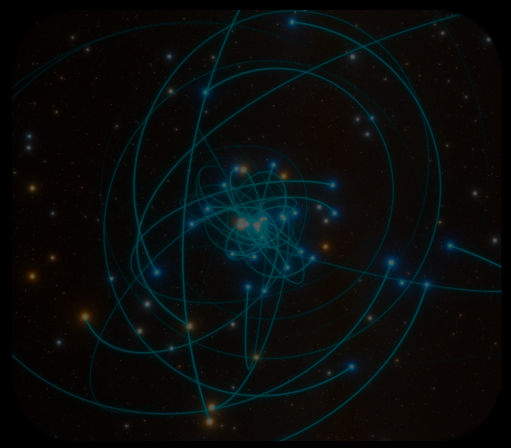


Gravitational Wave Astrophysics

Galactic Center?



Stellar Clusters?

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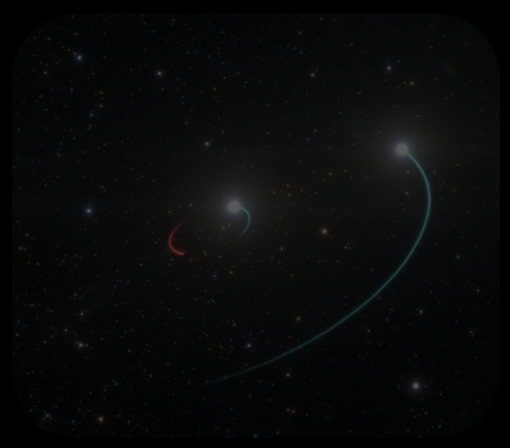

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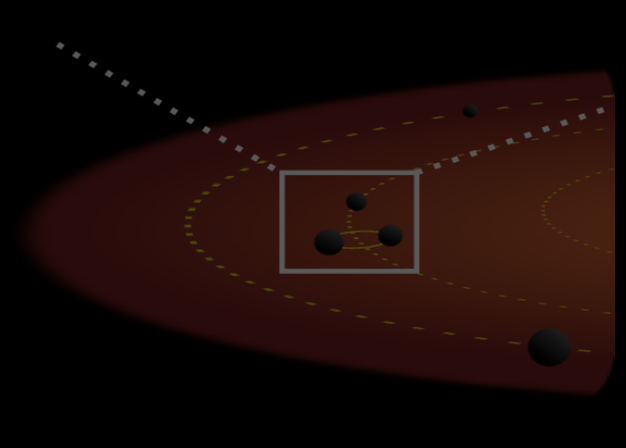
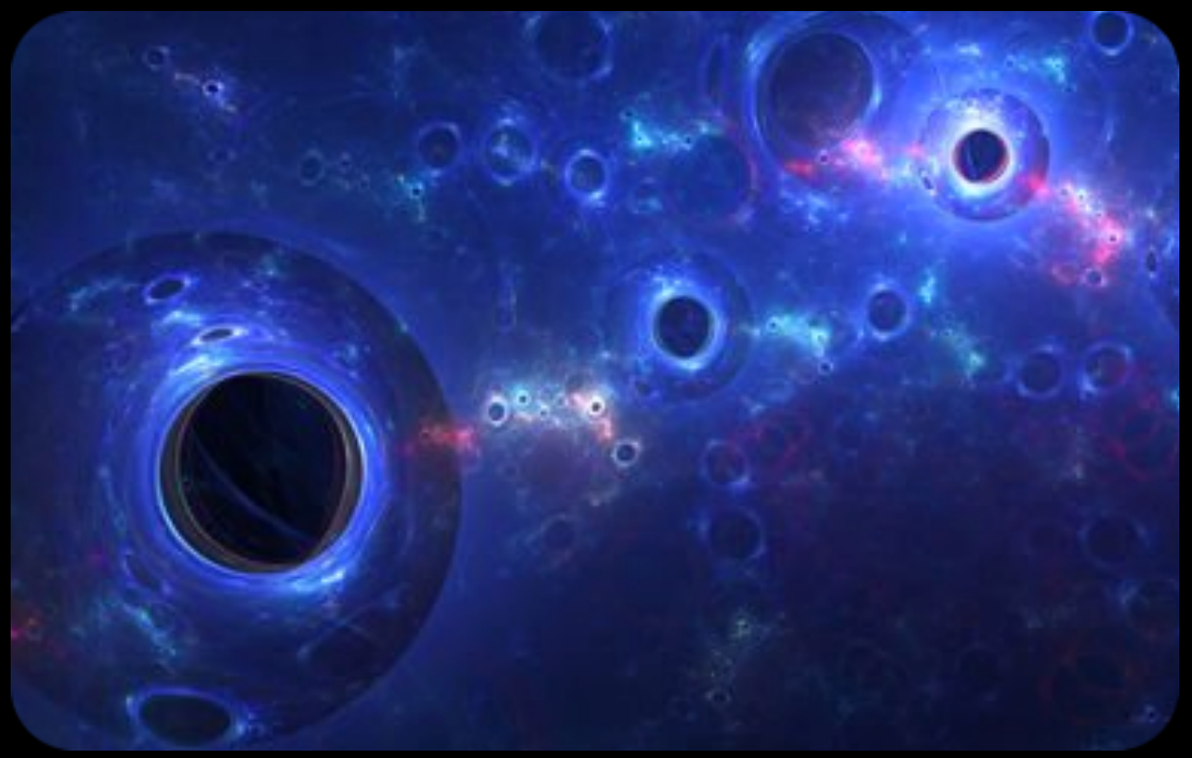


Something Else?



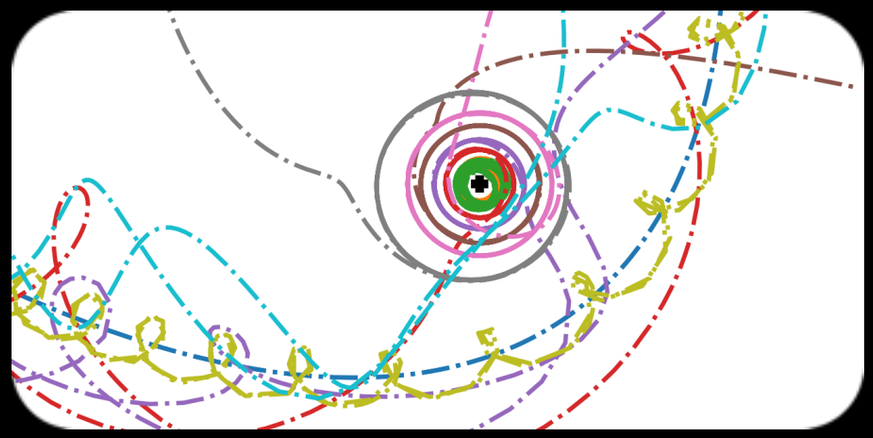
Gravitational Wave Astrophysics

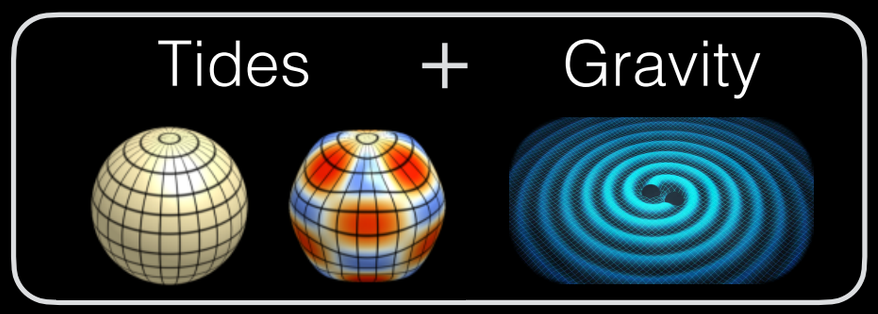
Research Interests:

Gravitational Wave Astrophysics

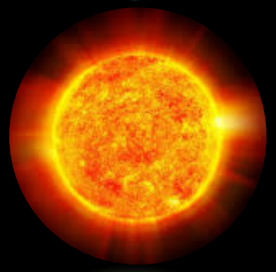
Research Interests:

Chaotic Interactions





Neutron star



Star

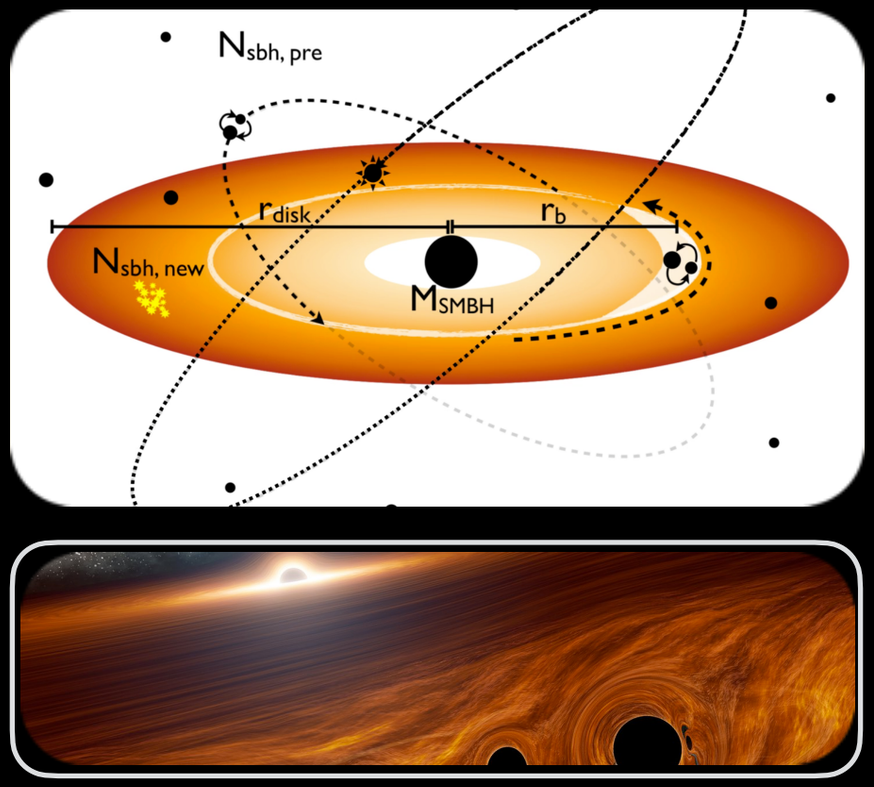
White dwarf

Black Hole

Gravitational Wave Astrophysics

Research Interests:

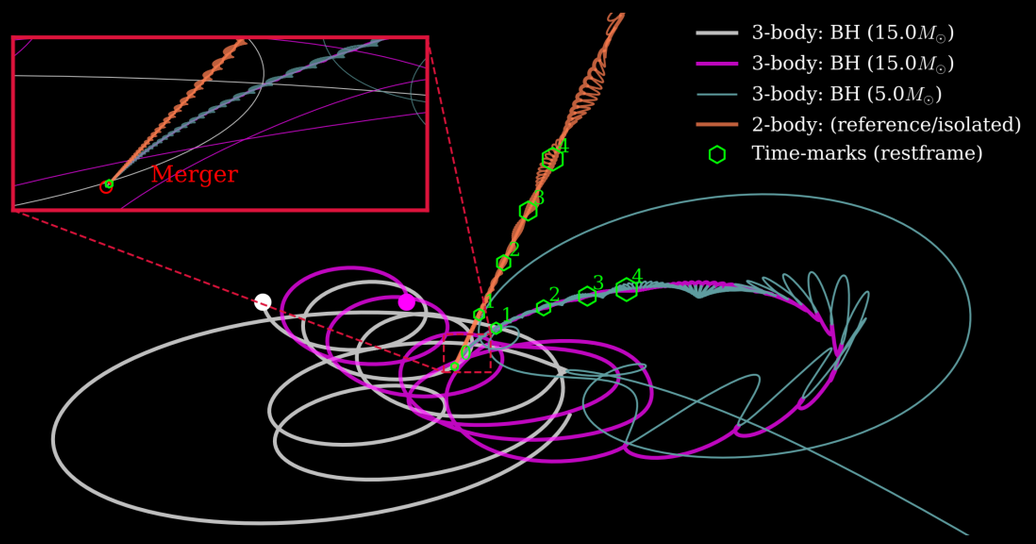
Black Holes & Discs

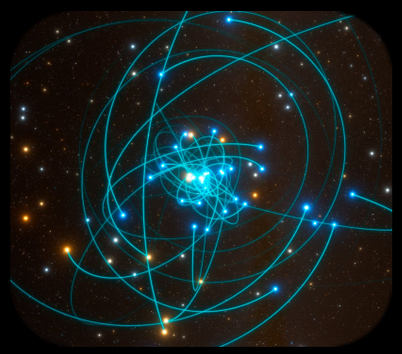


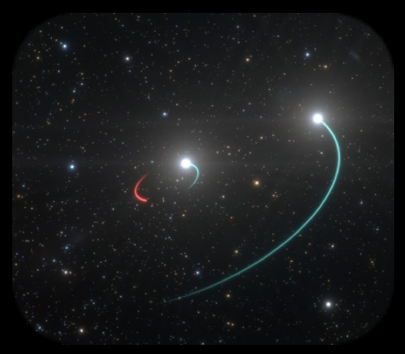
Gravitational Wave Astrophysics

Research Interests:

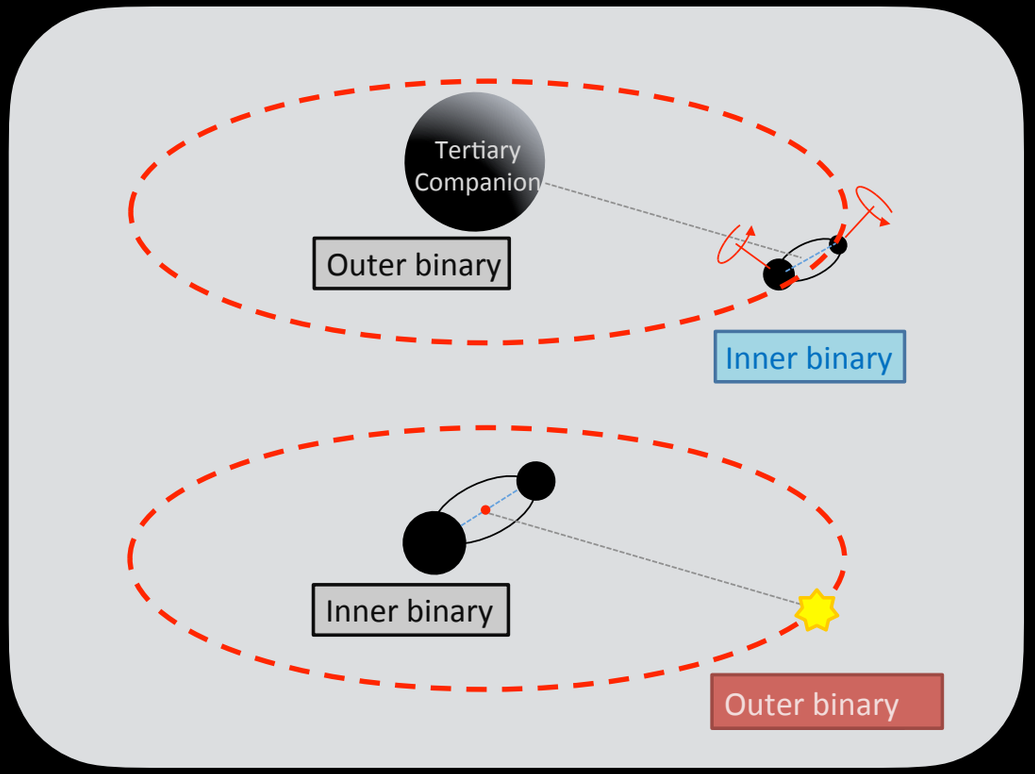
Perturbed Black Hole Mergers





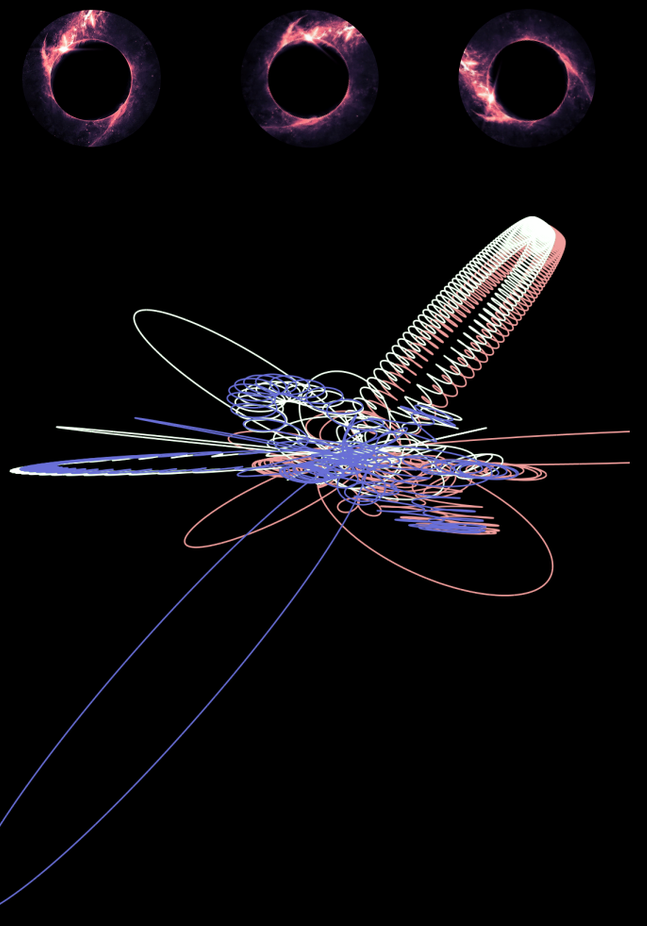


Secular Dynamics

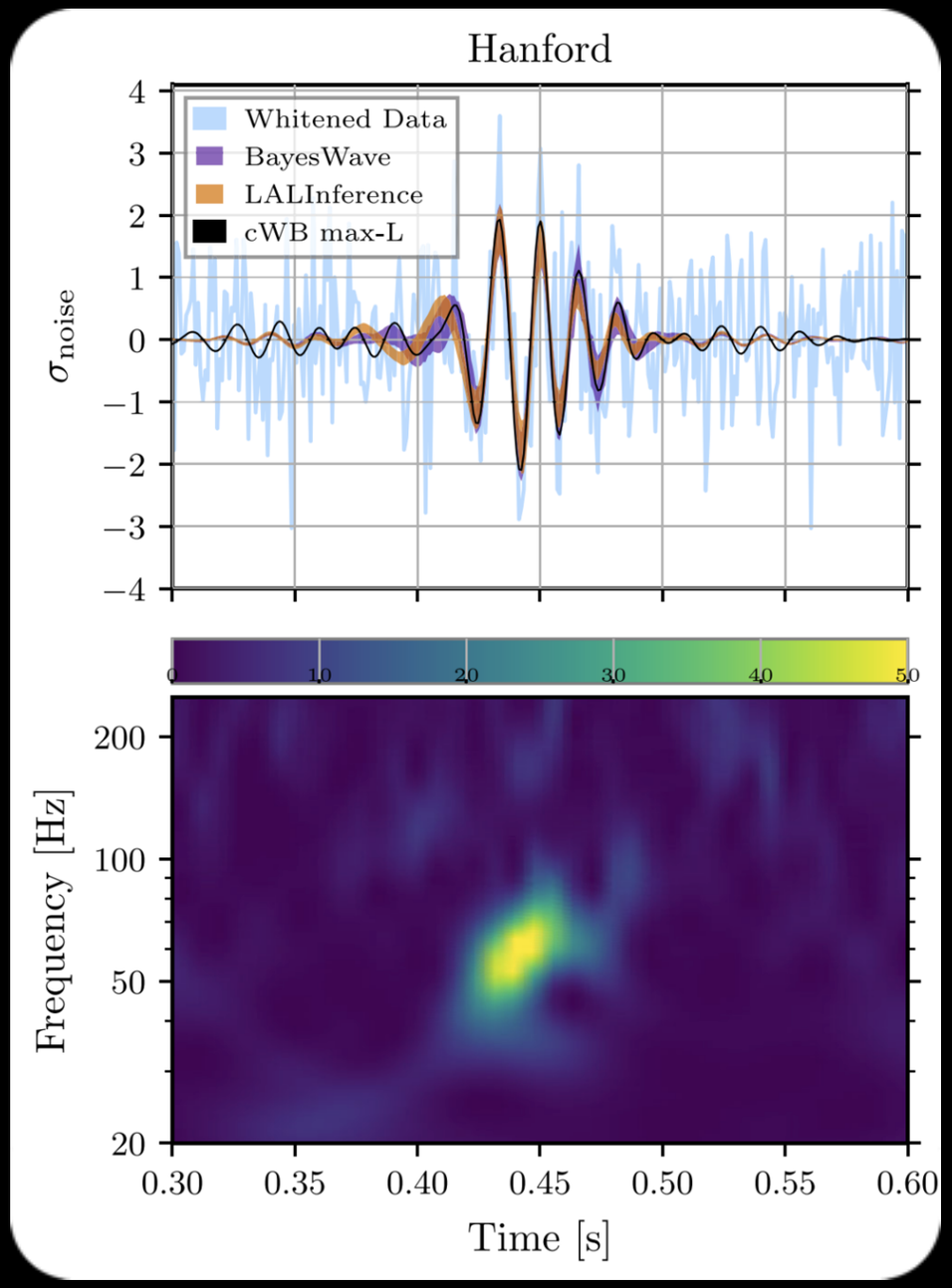


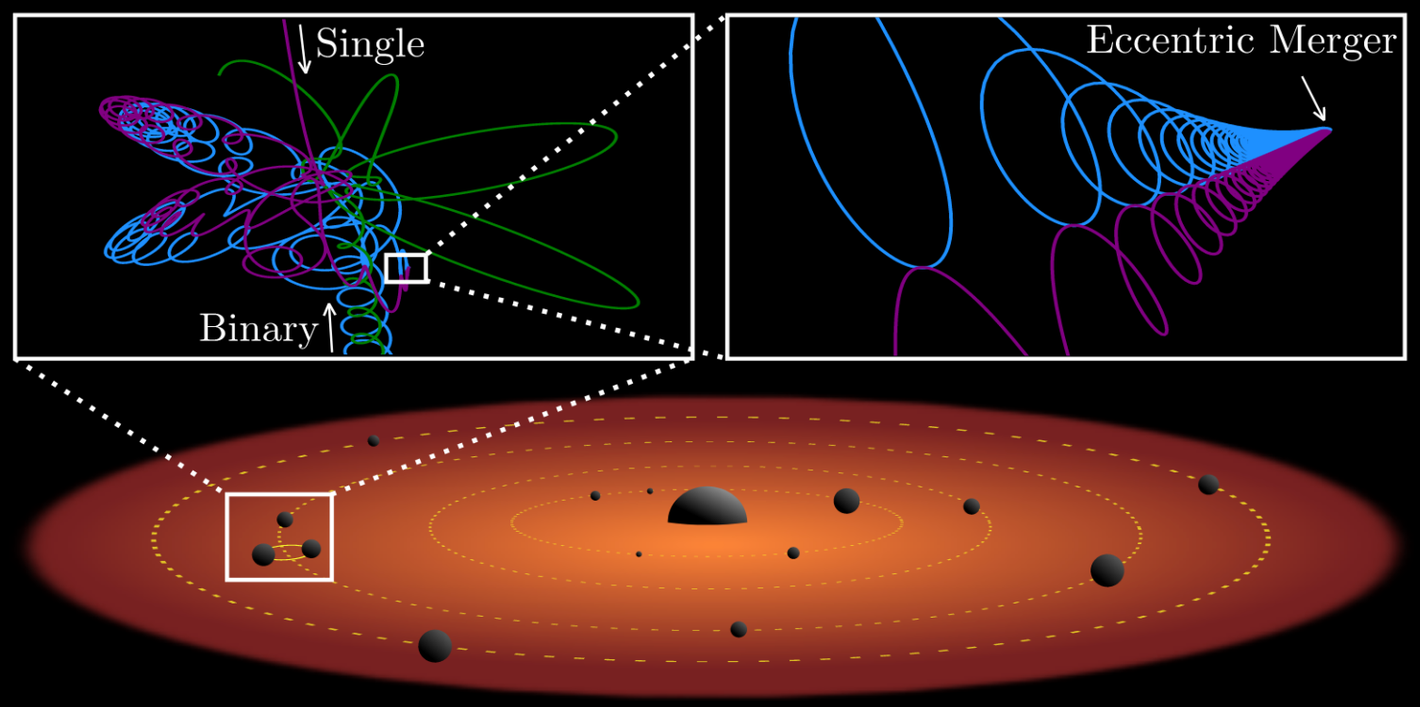
Gravitational Wave Astrophysics

Black Hole Interactions

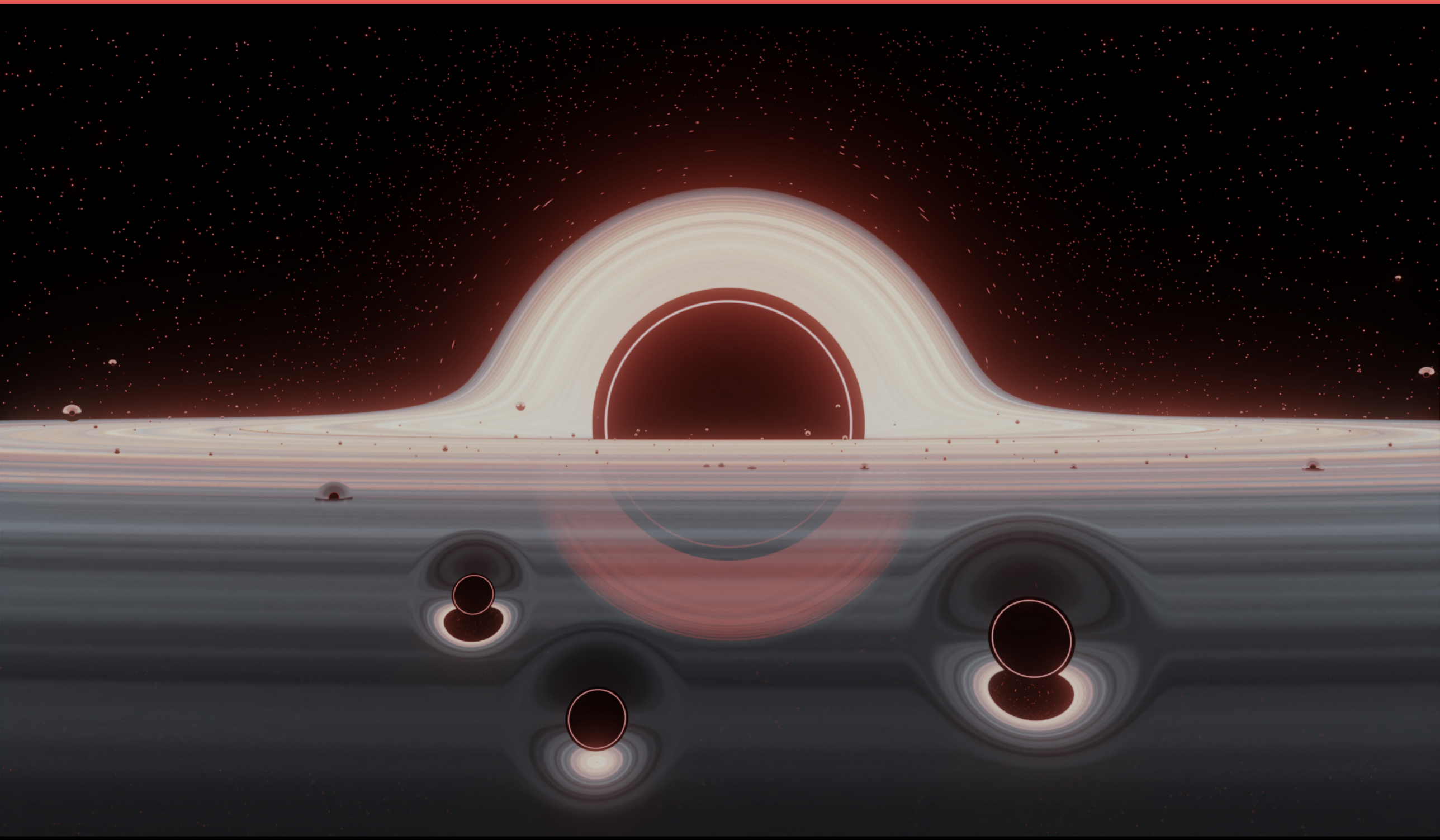


Research Highlight





Gravitational Wave Astrophysics



The Gravitational Wave Sky

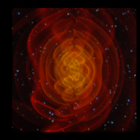
The Gravitational Wave Spectrum

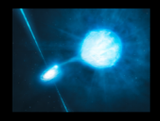
Sources

Stellar Mass COBs

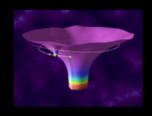
Big Bang

Supermassive Black Hole Binary Merger

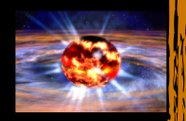




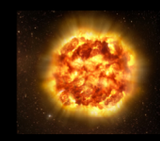
Compact Binary Inspiral & Merger

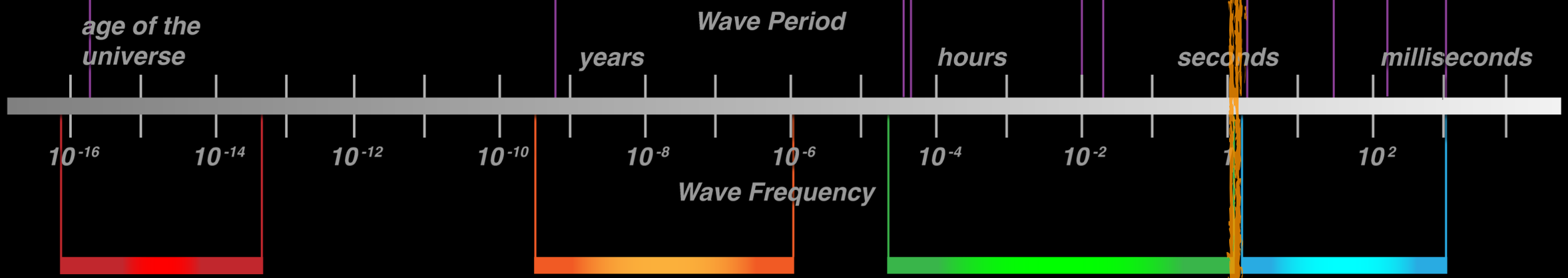


Extreme Mass-Ratio Inspirals



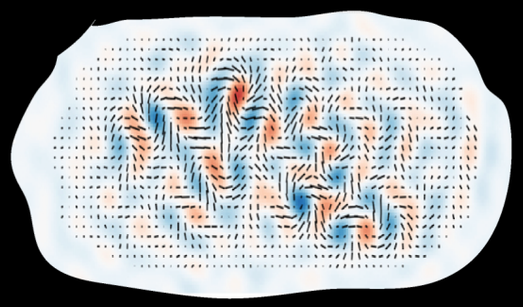
Pulsars, Supernovae



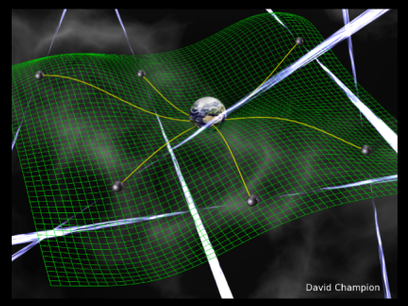


Detectors

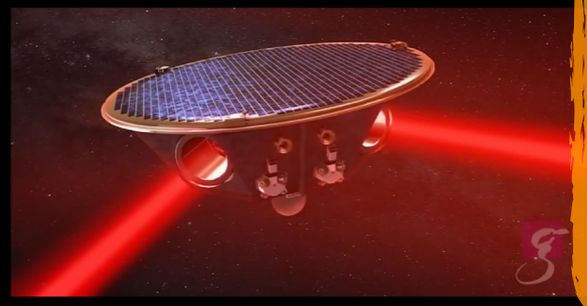
CMB Polarization



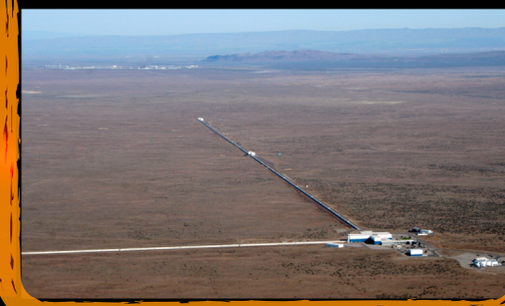
Radio Pulsar Timing Arrays



Space-based interferometers



Terrestrial interferometers



LIGO/VIRGO/KAGRA+

The Low Frequency Gravitational Wave Sky

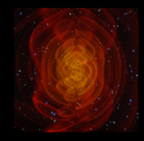
The Gravitational Wave Spectrum

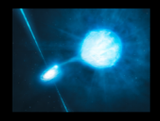
Sources

Supermassive Black Hole Binaries

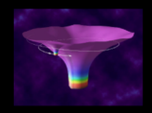
Big Bang

Supermassive Black Hole Binary Merger





Compact Binary Inspiral & Merger



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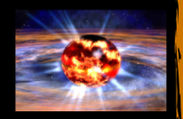


Pulsars, Supernovae

age of the universe

Wave Period

years

hours

seconds

milliseconds

10^{-16} 10^{-14} 10^{-12} 10^{-10} 10^{-8} 10^{-6} 10^{-4} 10^{-2} 1 10^{2}

Wave Frequency

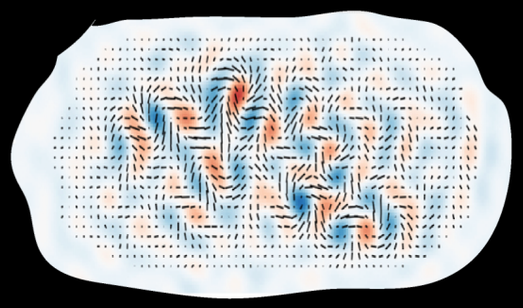
CMB Polarization

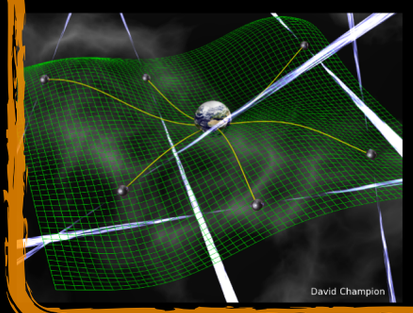
Radio Pulsar Timing Arrays

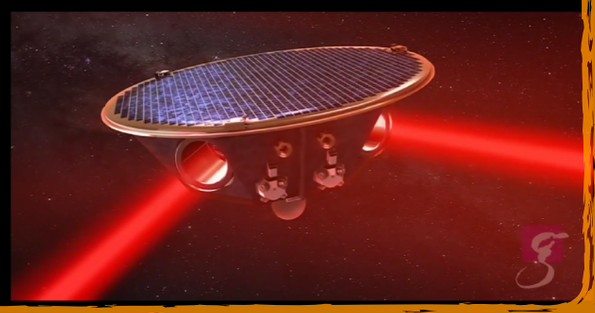
Space-based interferometers

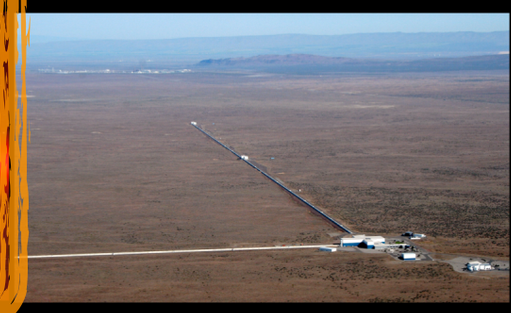
Terrestrial interferometers

Detectors







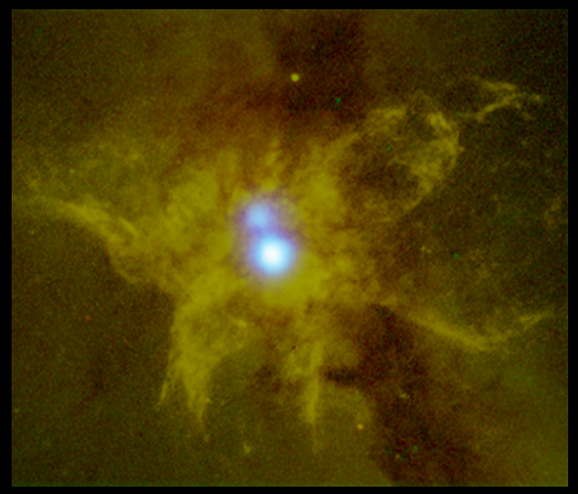


PTAs

LISA

GALAXIES MERGE, BUT DO THE BLACK HOLES (AND HOW)?

* **Step 1:** *Galaxy merger* forms a supermassive black hole binary via dynamical friction

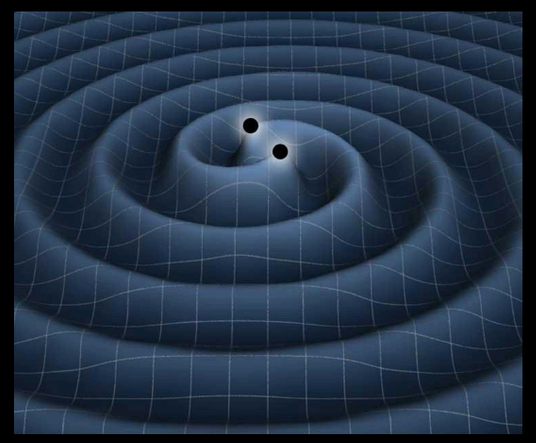


Far apart

Closer together

* **Step 2:** *???*

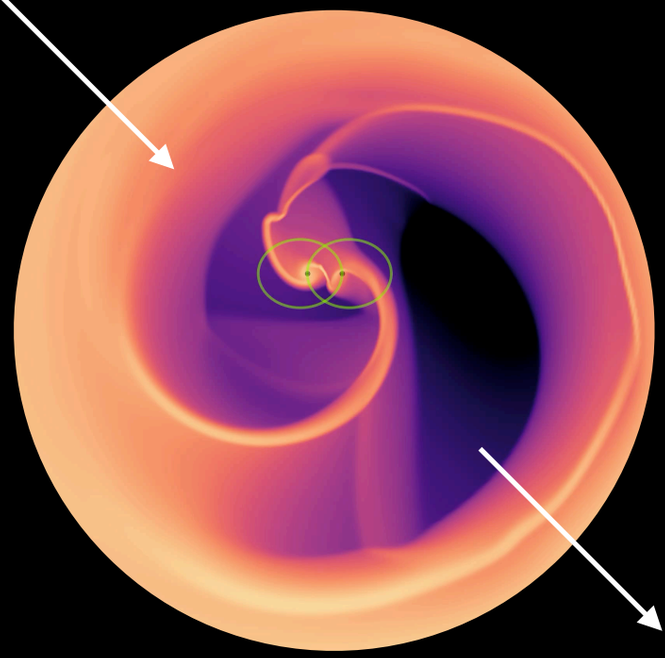
Open Question
(Final Parsec Problem):
Do supermassive black hole binaries merge? What mediates these mergers?



* **Step 3:** *Gravitational Waves* merge the supermassive black holes

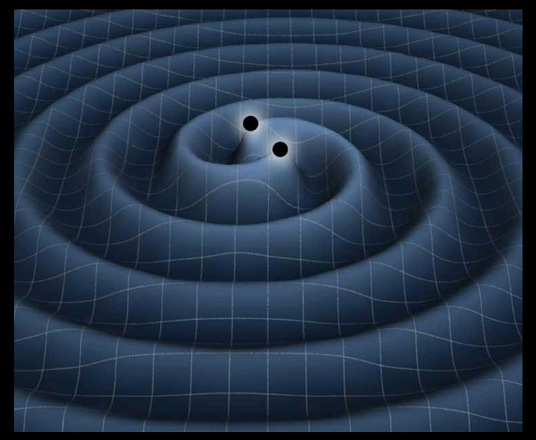
GALAXIES MERGE, BUT DO THE BLACK HOLES (AND HOW)? HOW DO WE FIND OUT?

* **Step 1:** *Galaxy merger* forms a supermassive black hole binary via dynamical friction



Far apart

Closer together

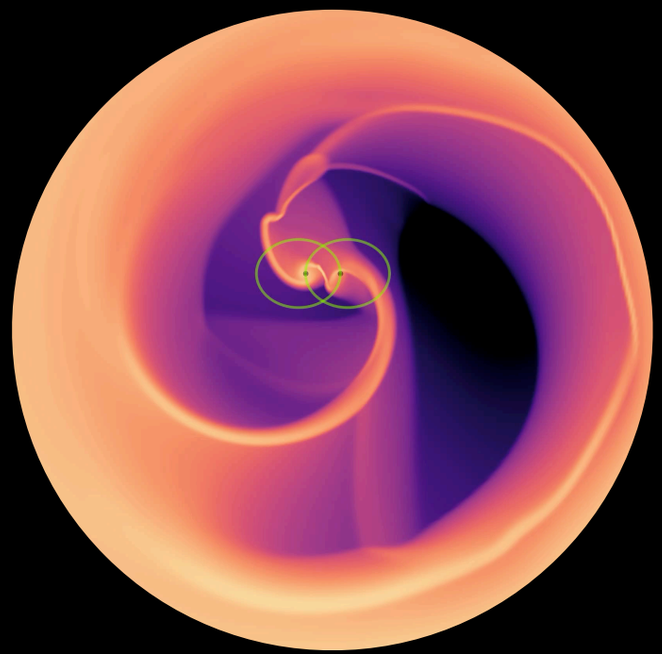


* **Step 2:** *???*

Understand binary interactions with environment

* **Step 3:** *Gravitational Waves* merge the supermassive black holes

GALAXIES MERGE, BUT DO THE BLACK HOLES (AND HOW)?
HOW DO WE FIND OUT?

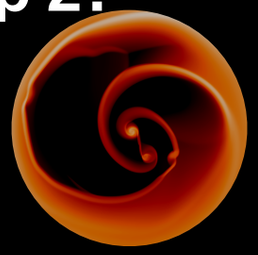


Population Predictions

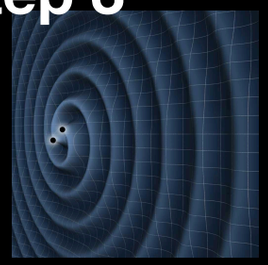
How does gas affect the orbit and drive the black holes to merge?

Step 1

Step 2?

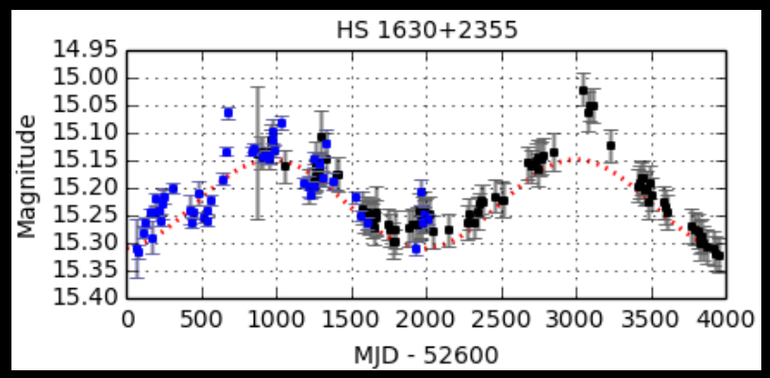


Step 3



Discovery: Take a Census

How does the accretion of gas make the binary discoverable?

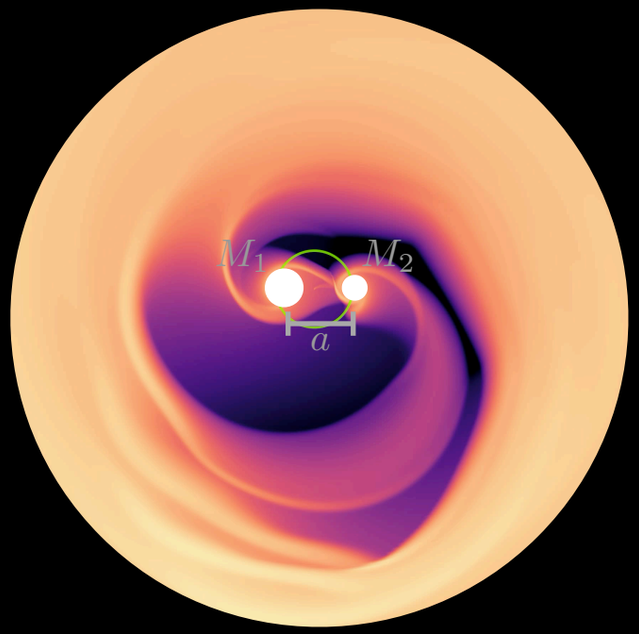


BINARY+GAS DYNAMICS AND SUPERMASSIVE BLACK HOLES
OVERVIEW OF WORK AT NBIA

Focus Areas

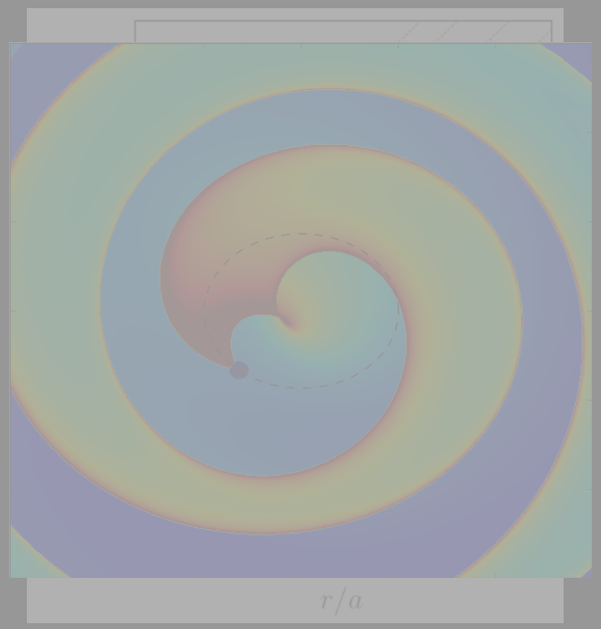
*** Numerical Calculations**

Physics of gas response, orbital evolution, obs. signature



*** Pen & Paper Theory**

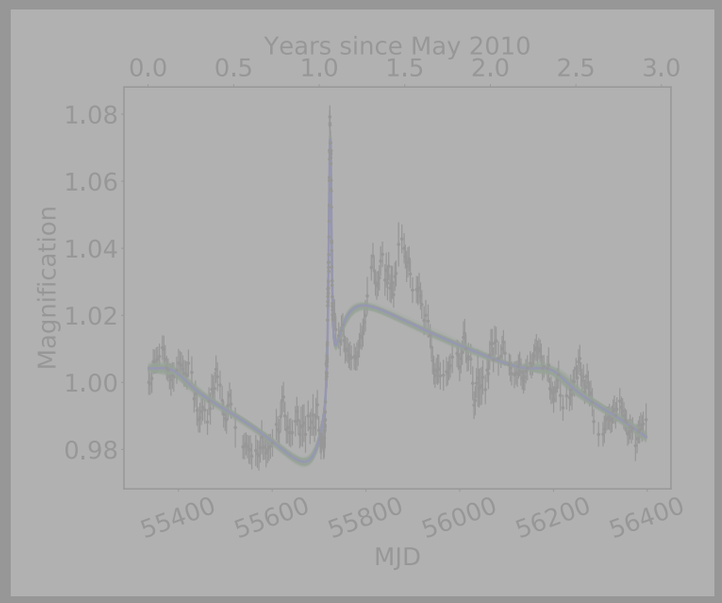
Interpretation of, and insight beyond, numerics



*** Application**

*To population models

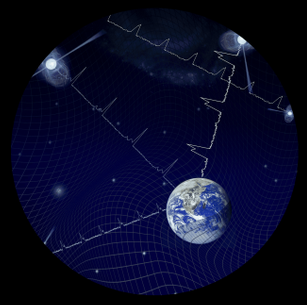
*To SBHB searches



People

Chris Tiede

MSc: Phillip Kirkeberg



Marcela Grcic

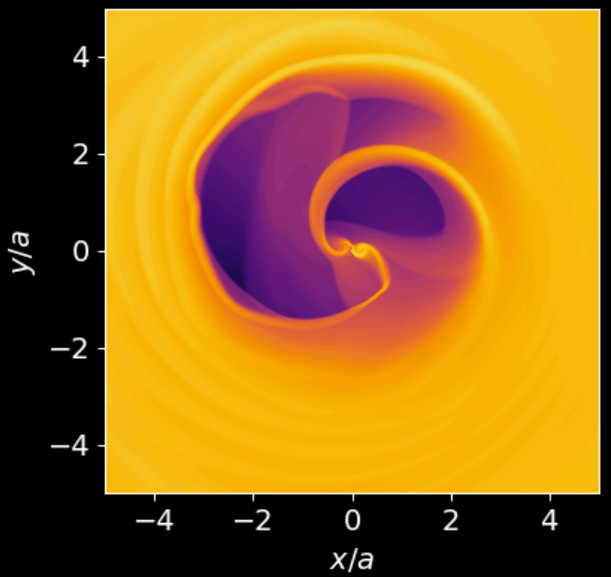
David O'Neill

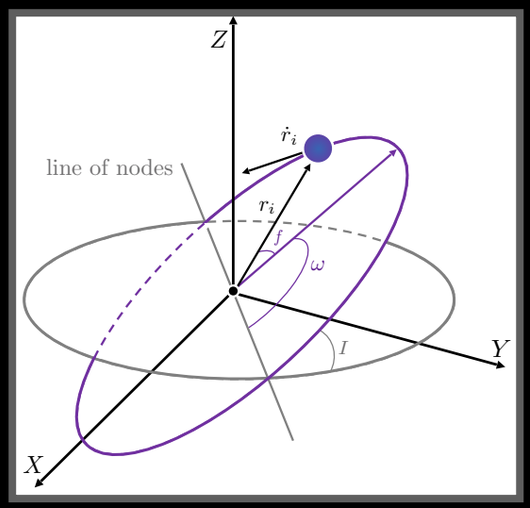
Martin Pessah

Lorenz Zwick

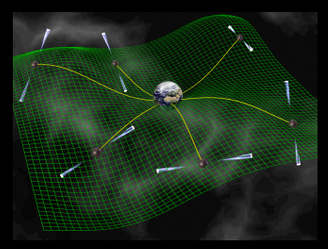
BINARY+GAS DYNAMICS AND SUPERMASSIVE BLACK HOLES
RESEARCH HIGHLIGHTS

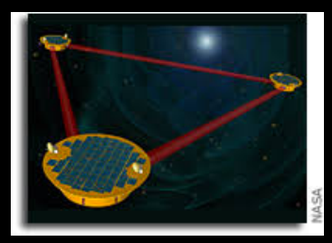
* **How does the binary orbit evolve?**
  - Has been disagreement on if gas causes binary to inspiral or outspiral
  - Founding members of field-wide code comparison project
  - Recent advances in orbital response for range of binary and disk parameters
  - Applications to newly discovered observations of *GWs with PTAs*





* **What electromagnetic signatures result from binary accretion?**





People

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Research Topics

* Theory at interface with observations: pencil-paper and numerics
* Gravitational waves and black hole astrophysics
* Many-body (relativistic) gravitational dynamics
* Gas accretion, gravitational lensing

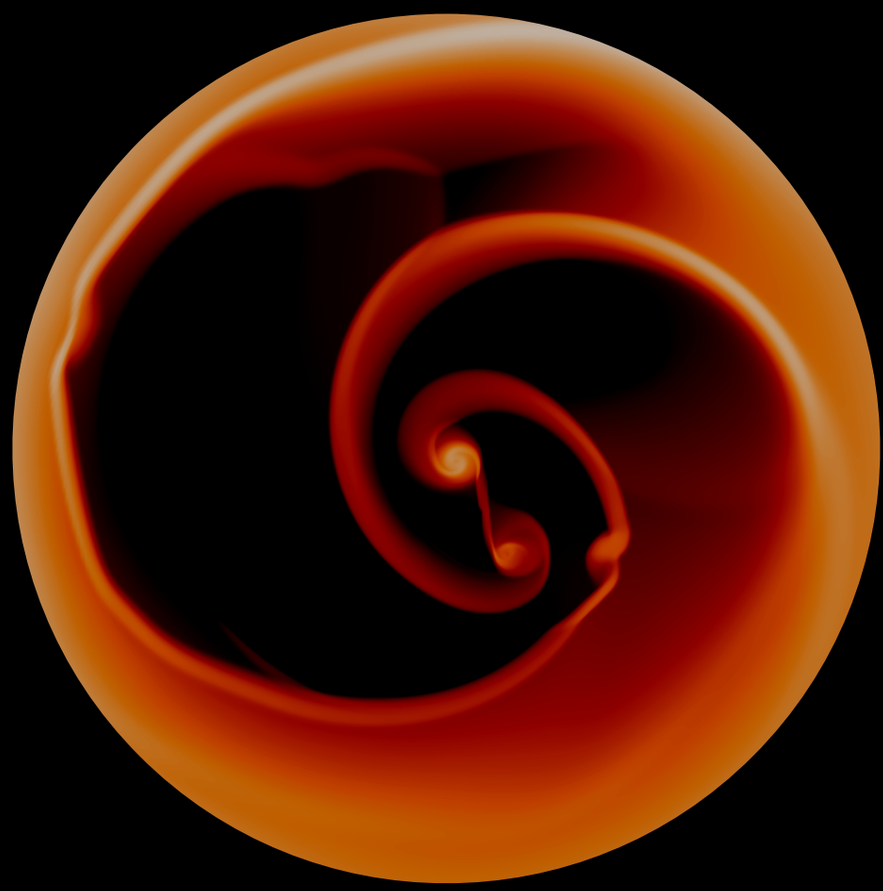
Open Questions

* How do black hole binaries (across the mass scale) form and merge?
  * How do we find evidence for supermassive black hole binaries?
  * Where/How do the stellar mass black hole binaries form/merge?
  * What Electromagnetic and Gravitational Wave observables can we predict and use to find answers?

IMPORTANT FOR YOUNG BINARY STARS AND PLANETS (2022 KITP WORKSHOP)

ALMA image of the young binary protostar BHB2007

Alves et al. 2019



Simulation of accretion onto an eccentric black hole binary

Recent Calculation

https://www.kitp.ucsb.edu/activities/binary22

Circumbinary Journal Club: Fridays at 11, NBIA