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ICTP-AP
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for Theoretical Physics Asia-Pacific
国际理论物理中心-亚太地区

Detection of Exotic Compact Objects with Extreme Mass Ratio Inspirals and mini-EMRIs

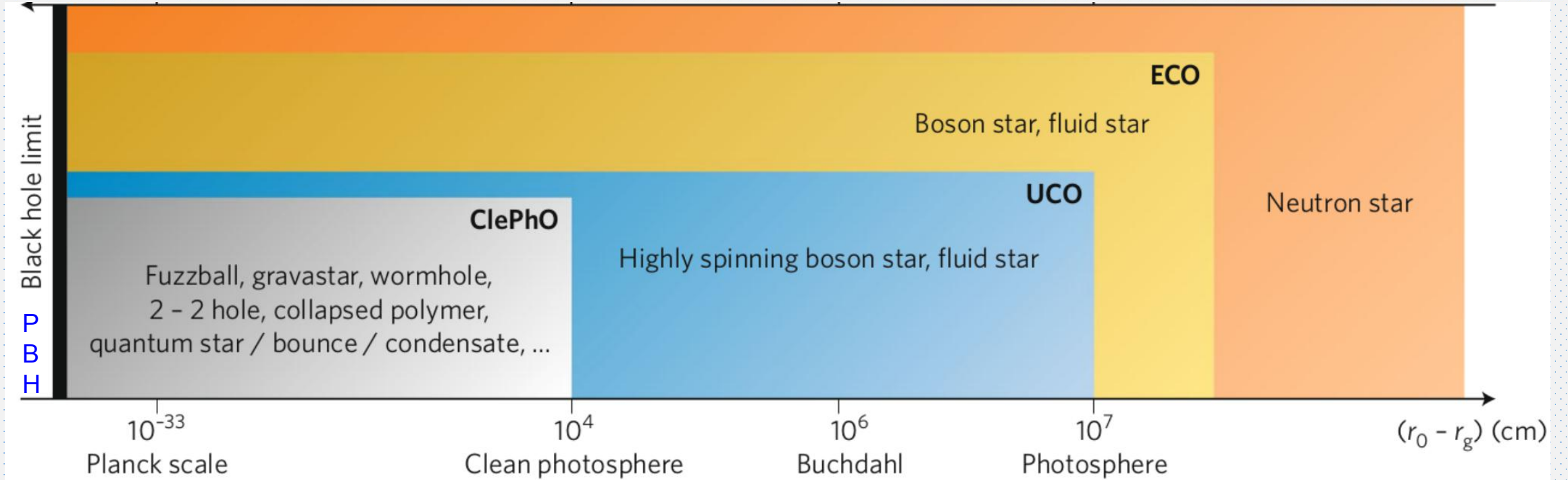
Huaike Guo

Jul. 12, 2024

MG17PESCARA  7-19 JULY 2024
SEVENTEENTH MARCEL GROSSMANN MEETING
ON RECENT DEVELOPMENTS IN THEORETICAL AND EXPERIMENTAL GENERAL RELATIVITY, ASTROPHYSICS AND RELATIVISTIC FIELD THEORIES

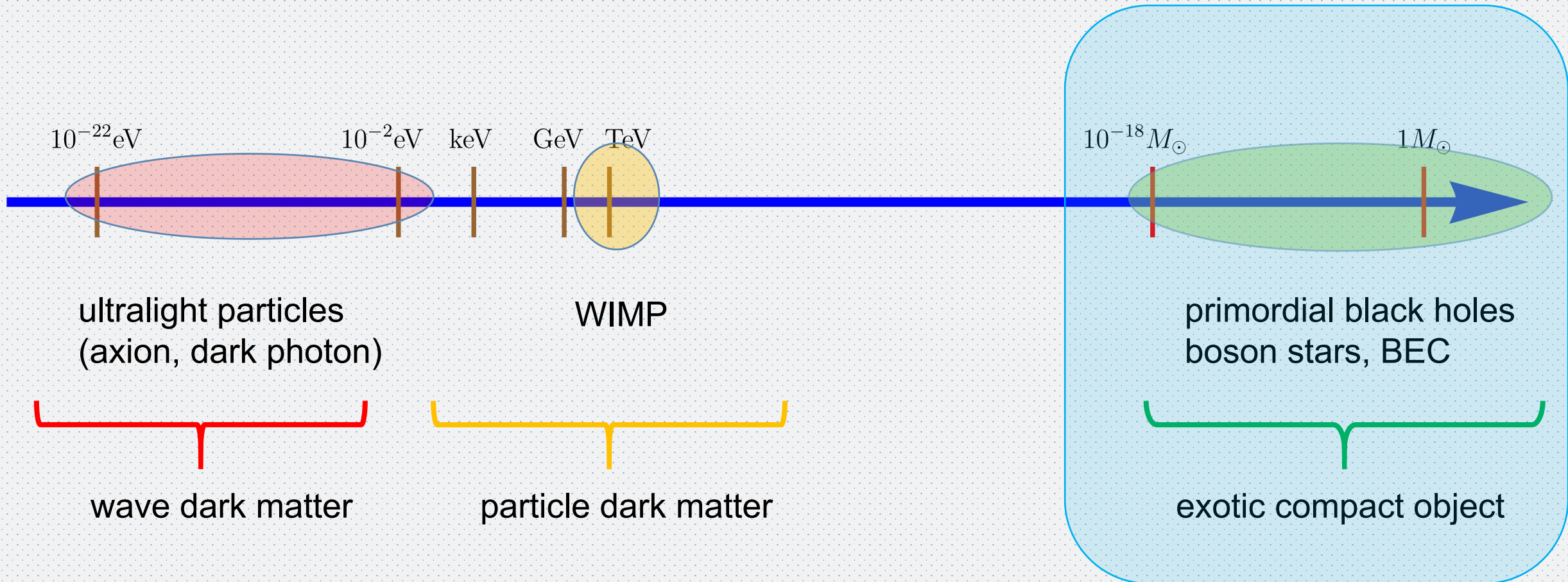
Exotic Compact Objects

Cardoso, Pani, Nature Astron [1709.01525]



ECO (this talk)

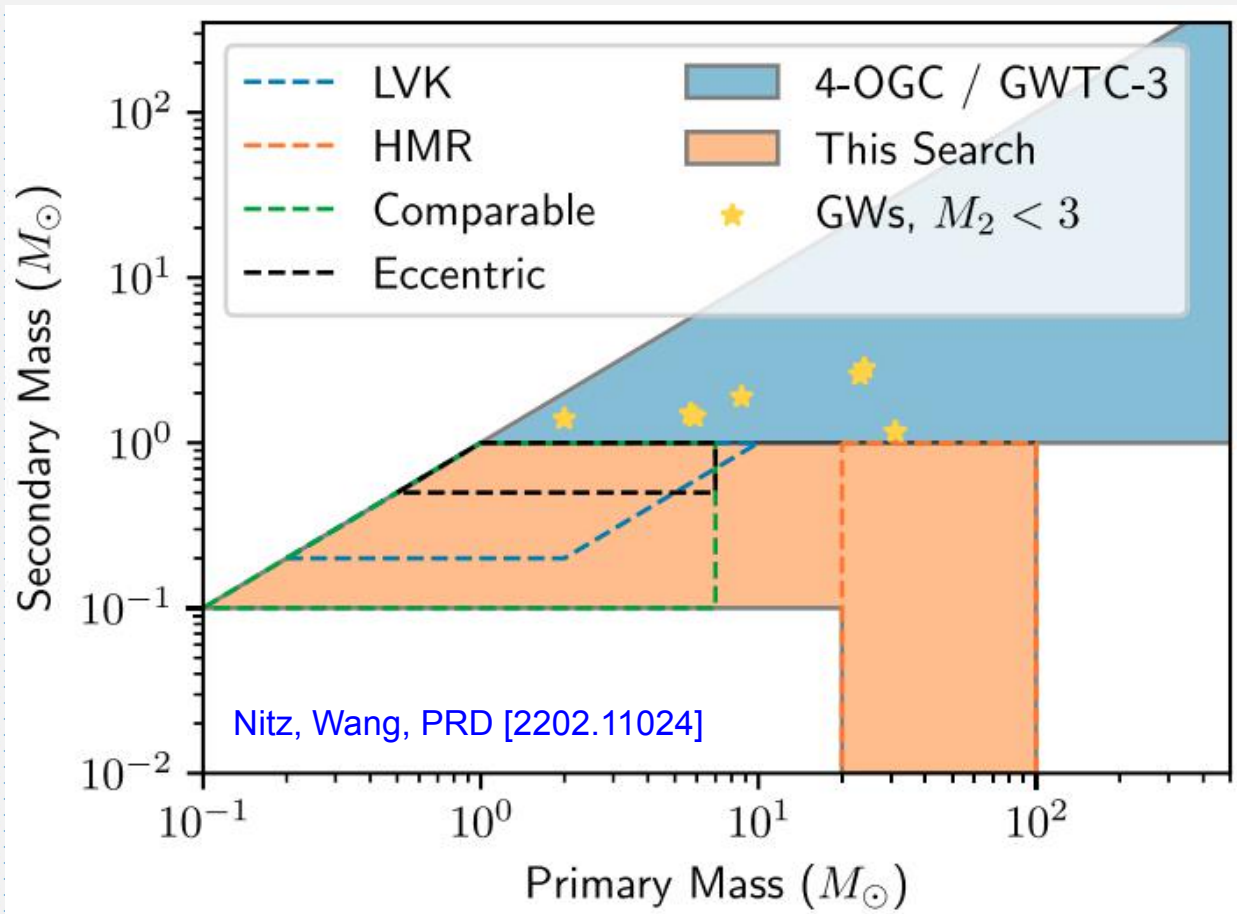
ECO as Dark Matter Candidates



Did LIGO detect ECOs?
subsolar compact object detection means something new

Subsolar ECO Searches

Rising interest in subsolar PBH searches (LVK, ...)



- Method: matched-filtering
- All assuming ultracompact objects

Need to take tidal disruption of ECO into account

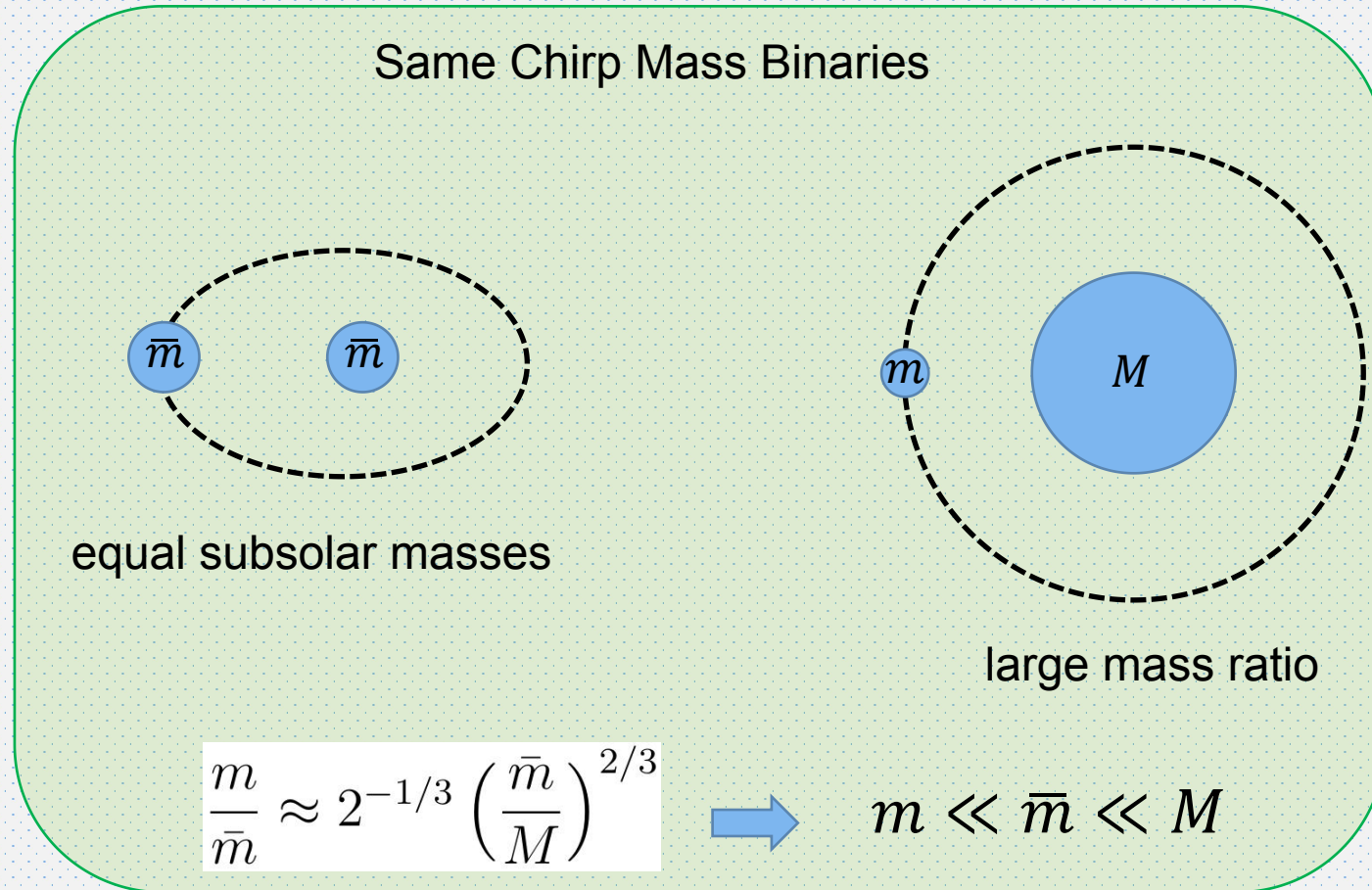
Signal decreases quickly as mass decreases (for comparable masses)

How to Search for Very Light ECO?

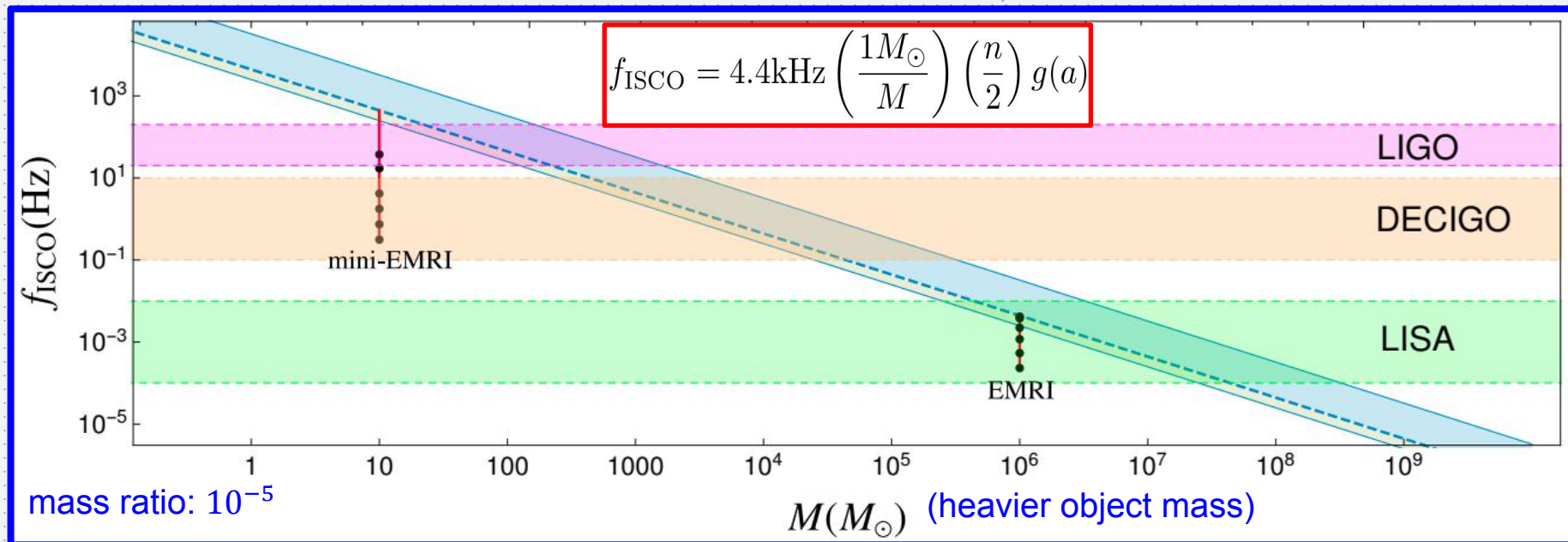
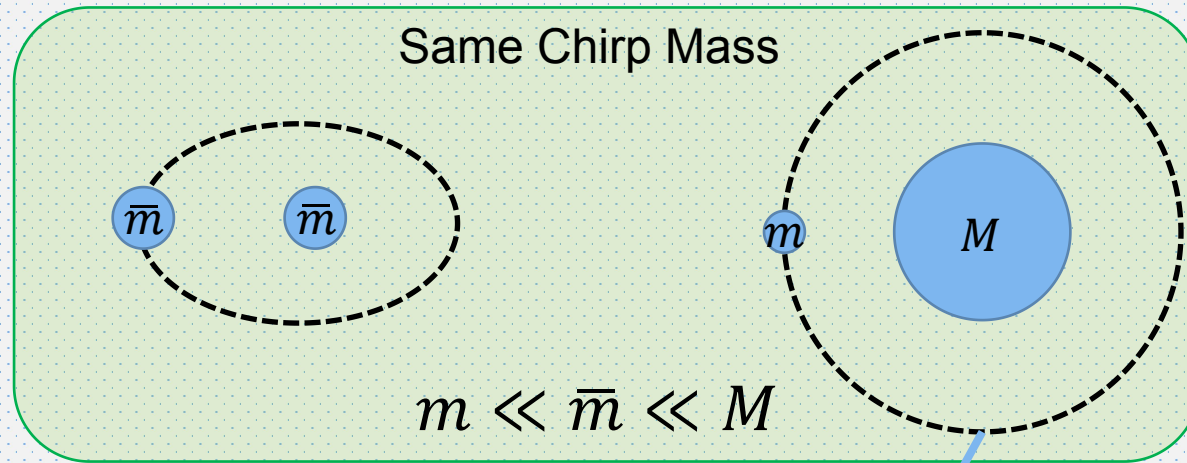
Signal becomes stronger as the chirp mass increases

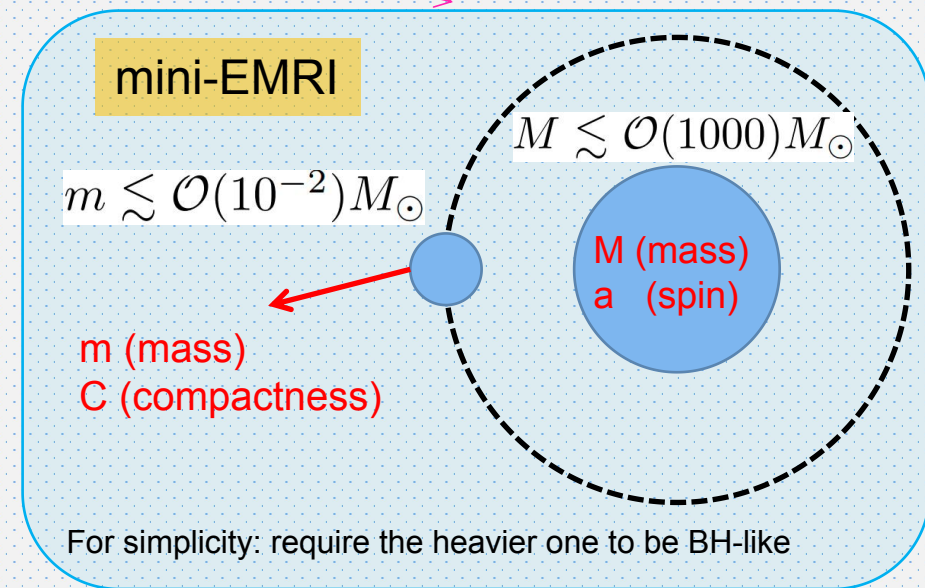
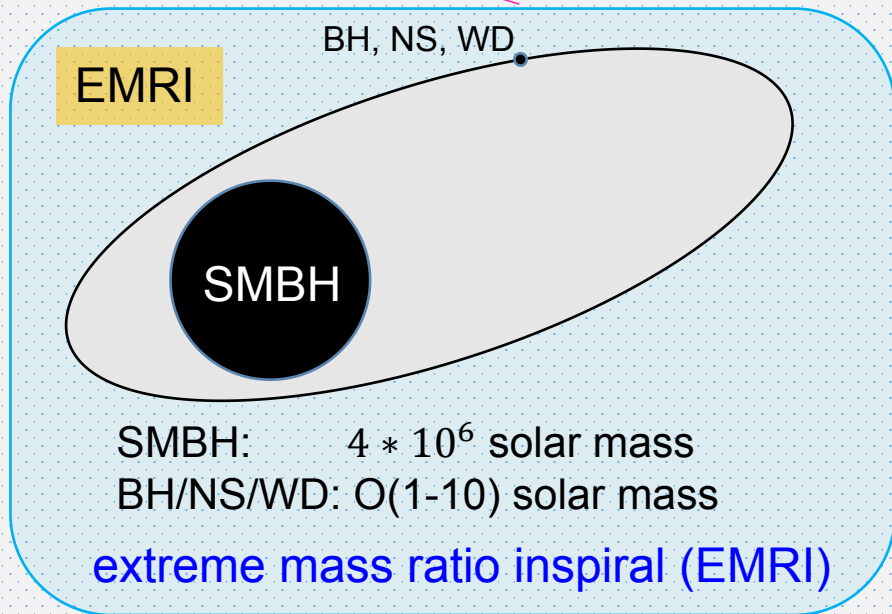
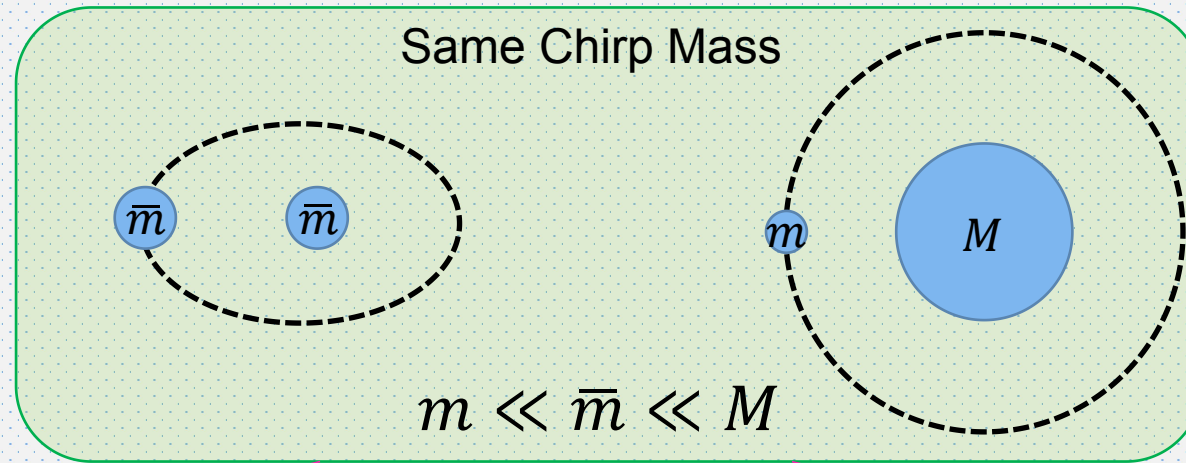
the chirp mass

$$M_c = \frac{(m_1 m_2)^{3/5}}{(m_1 + m_2)^{1/5}}$$



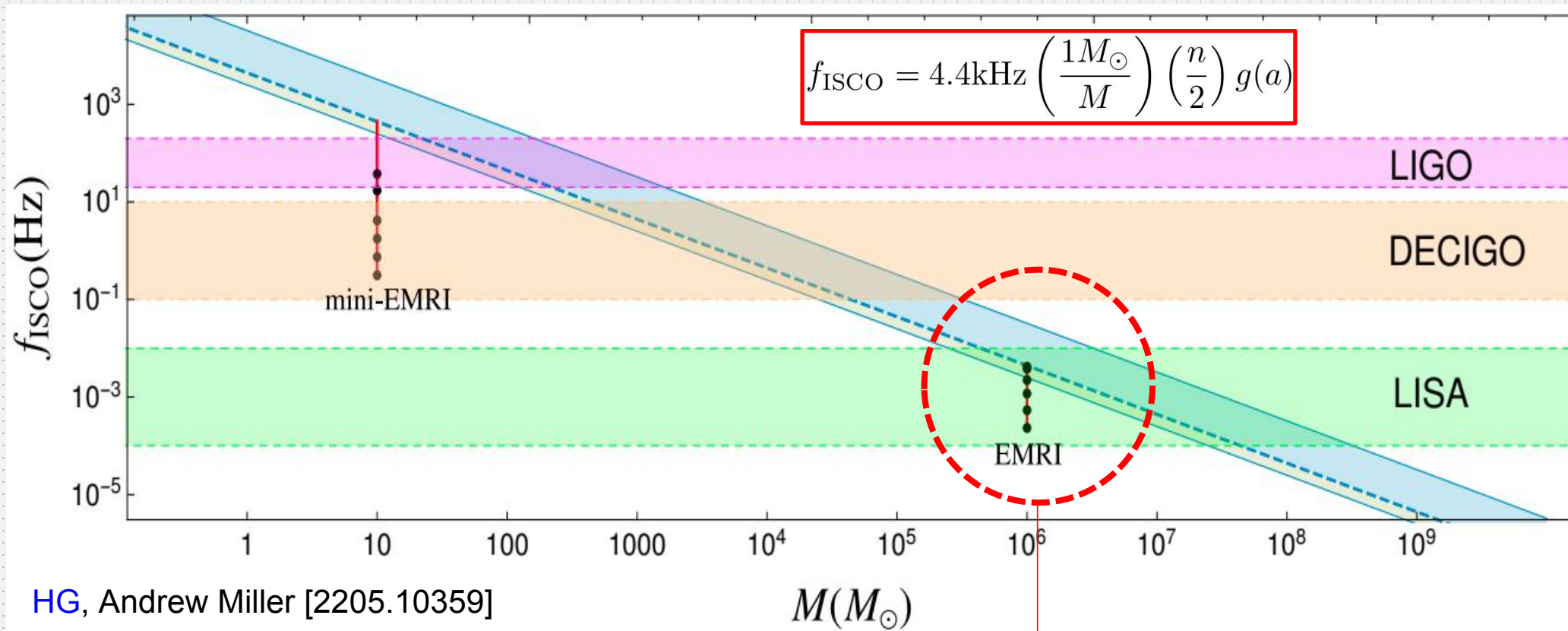
To probe a lighter one, make the other one heavier: larger mass ratio





Can search for much lighter ECO!

mini-EMRIs



HG, Andrew Miller [2205.10359]

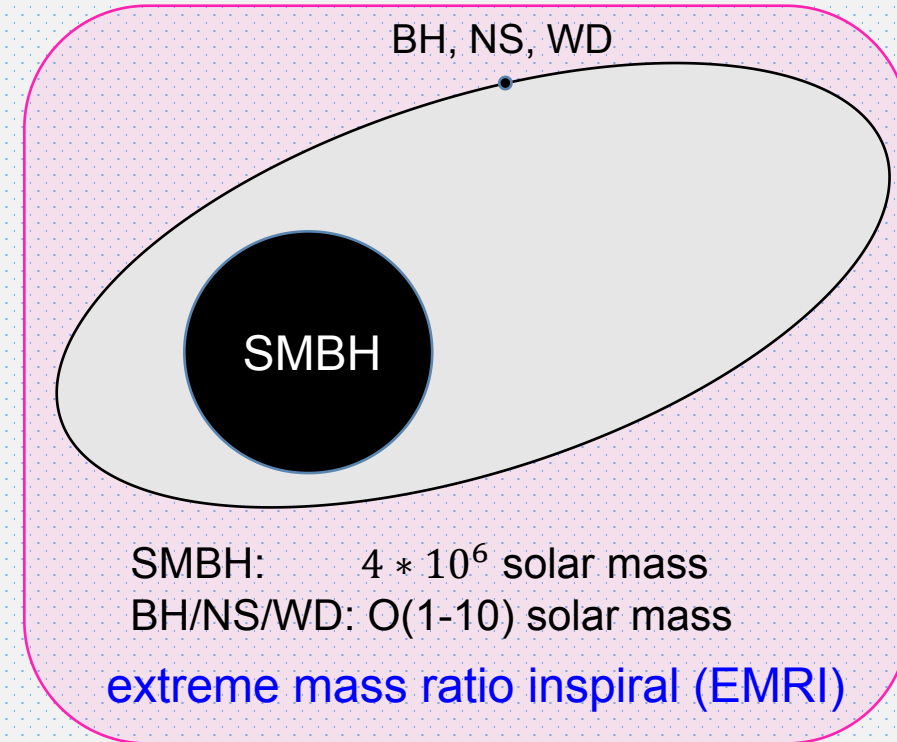
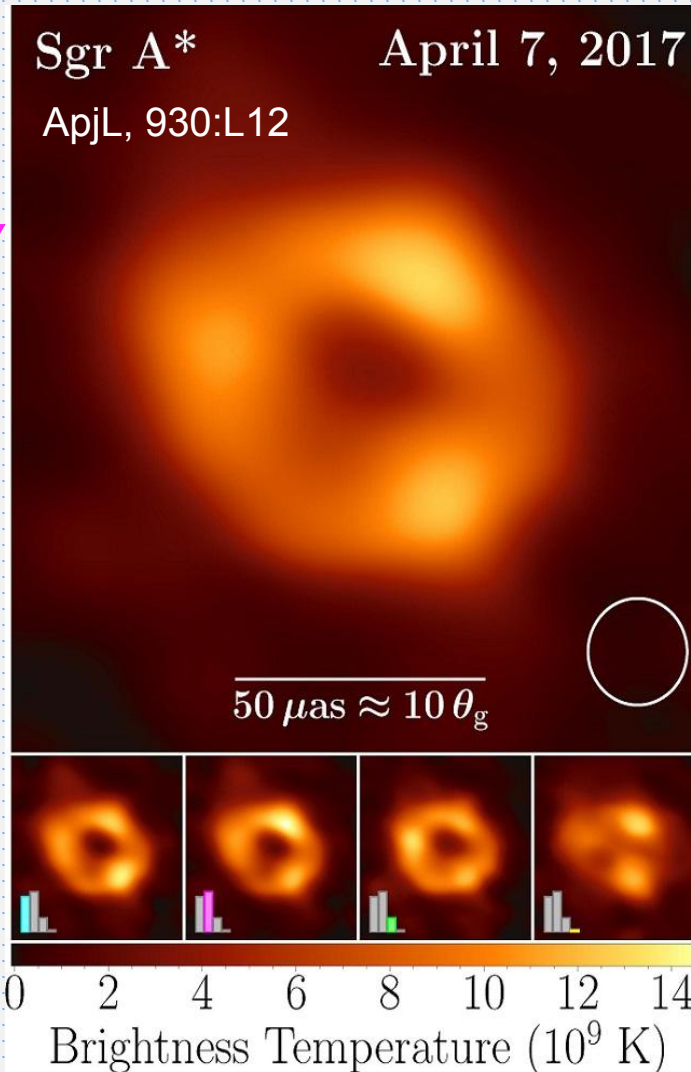
a standard EMRI system

The Extreme Mass Ratio Inspiral (EMRI)



Wikipedia

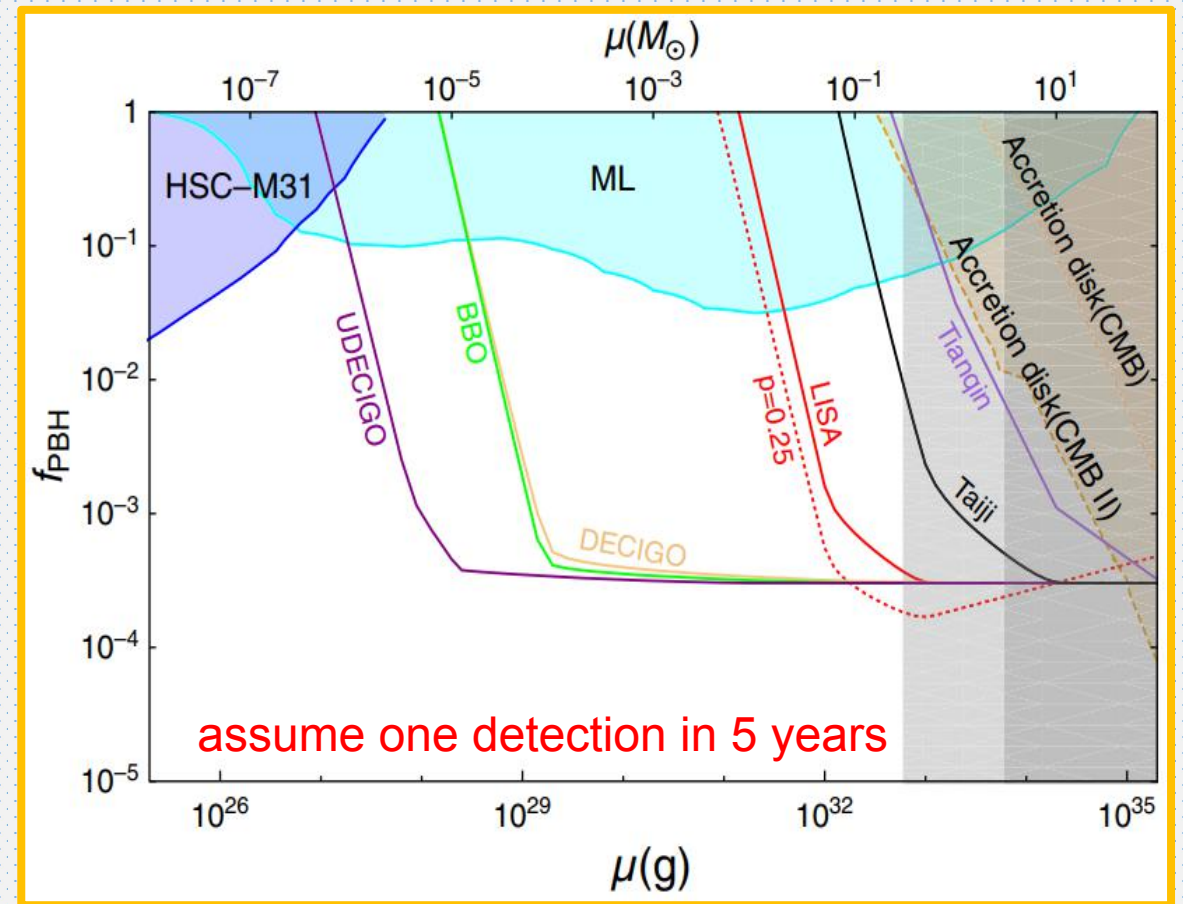
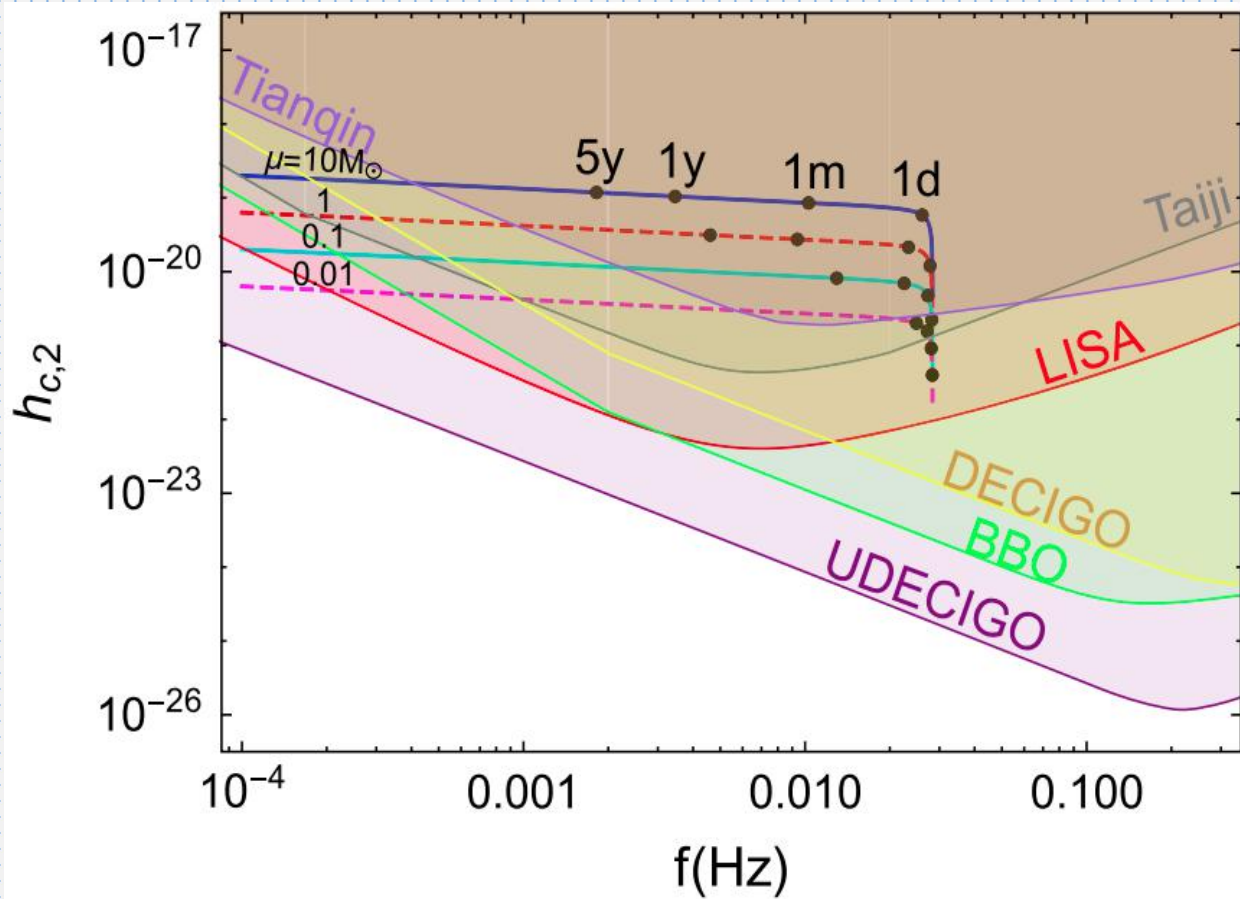
Babak et al, PRD [1703.09722]



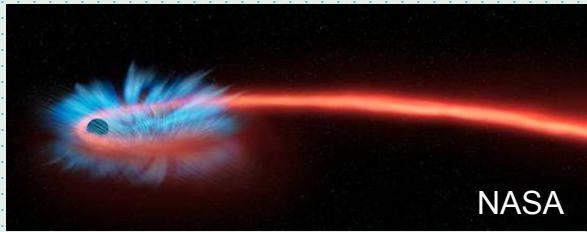
$$f_{\text{ISCO}} = 4.4 \text{ kHz} \left(\frac{1 M_{\odot}}{M} \right) \left(\frac{n}{2} \right) g(a)$$

Sensitivity to PBHs

- Can reach O(1000) events in 5 years

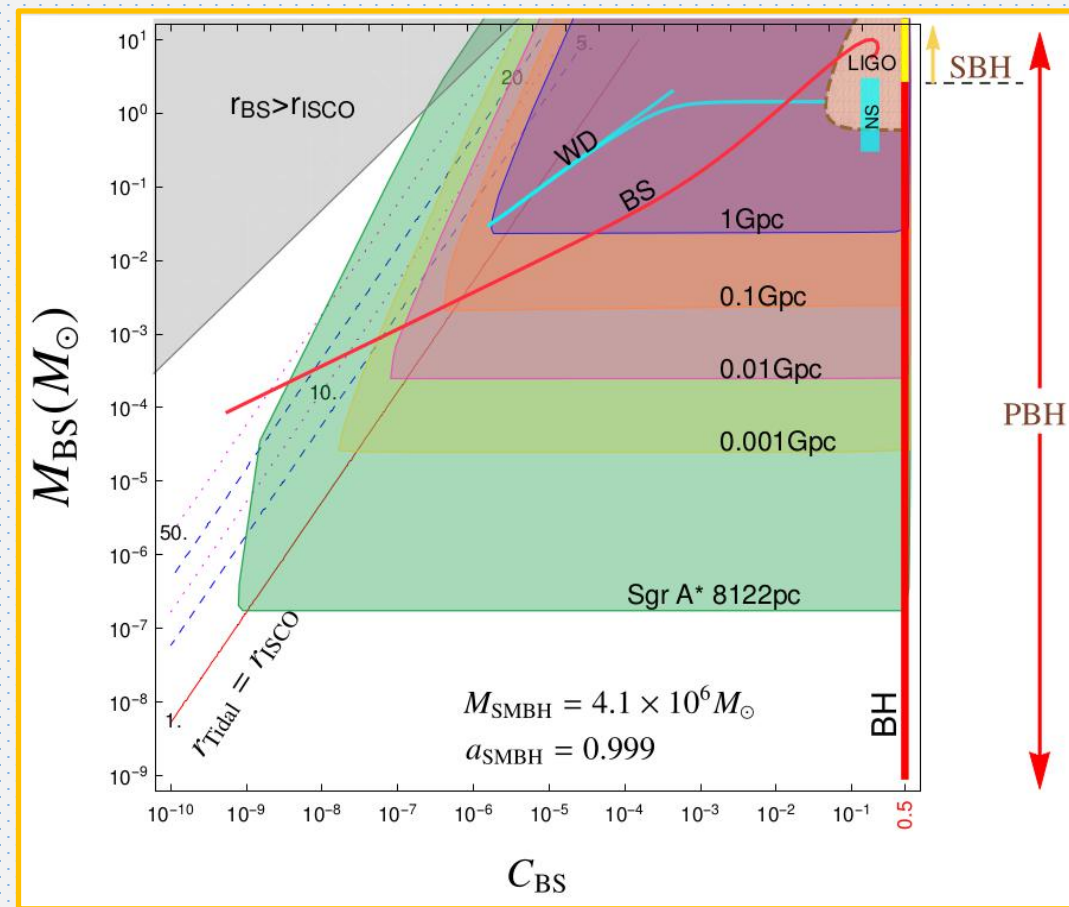
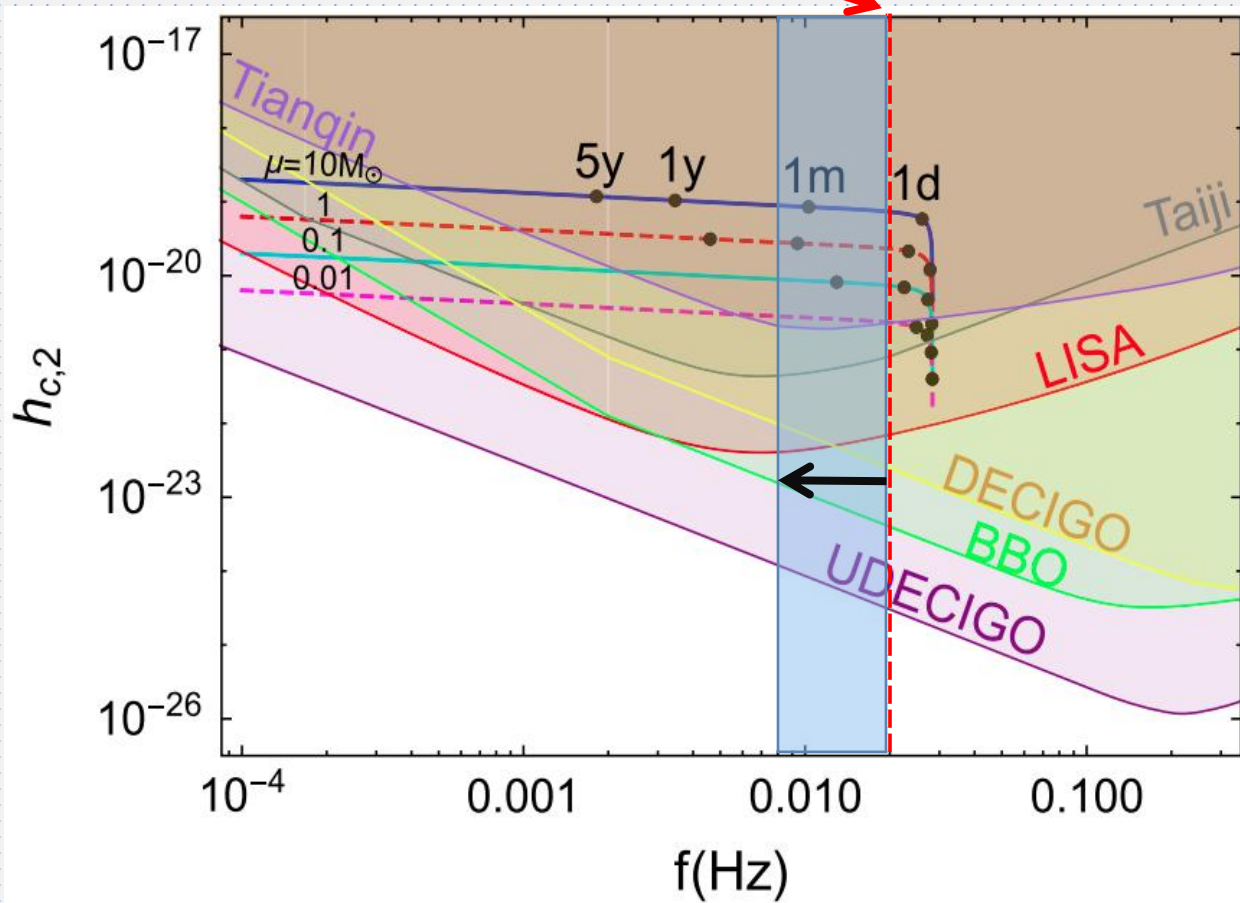


Tidal radius: $r_{\text{tidal}} = \frac{(m^2 M)^{1/3}}{C}$

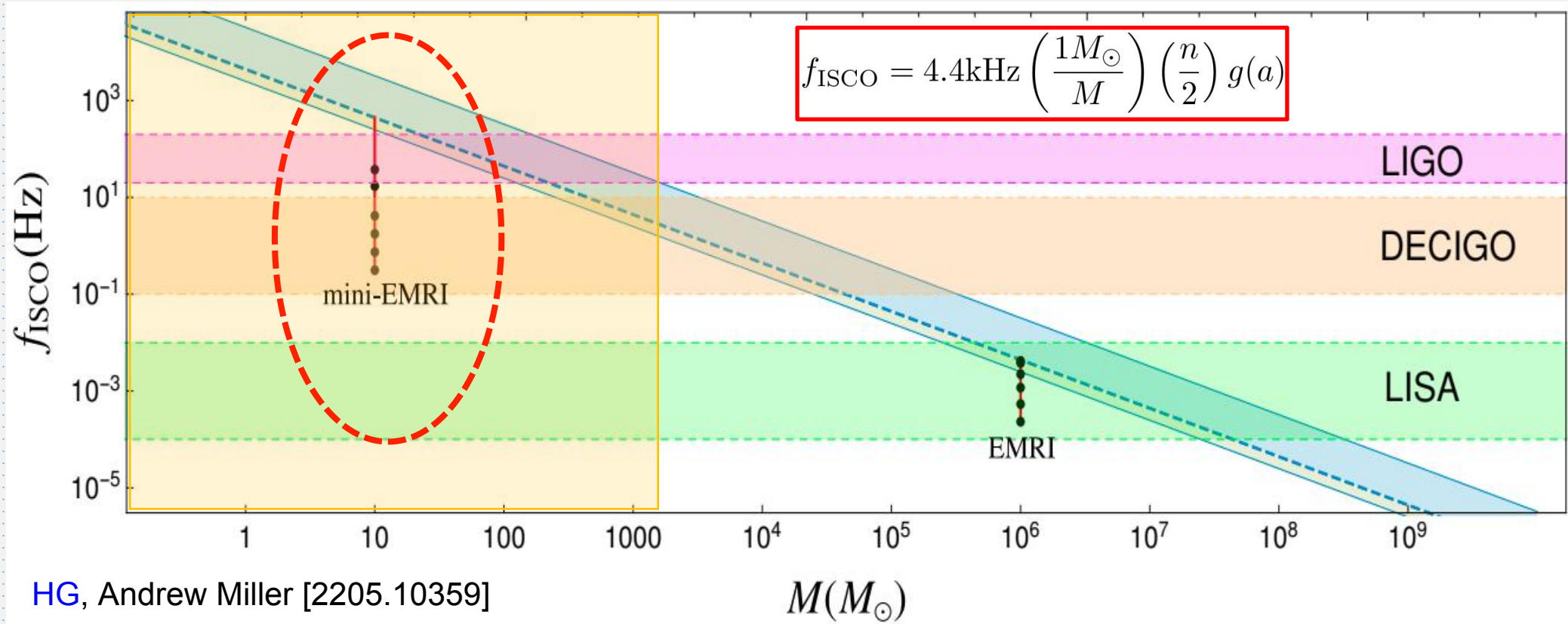


Sensitivity to Generic ECOs

tidal disruption



mini-EMRIs



Similar systems:

Davoudiasl, Giardino, Phys.Lett.B 768, 198 (2017)

Pan, Lyu, Yang, PRD 105, 083005 (2022)

Barsanti et al PRL 128, 111104 (2022)

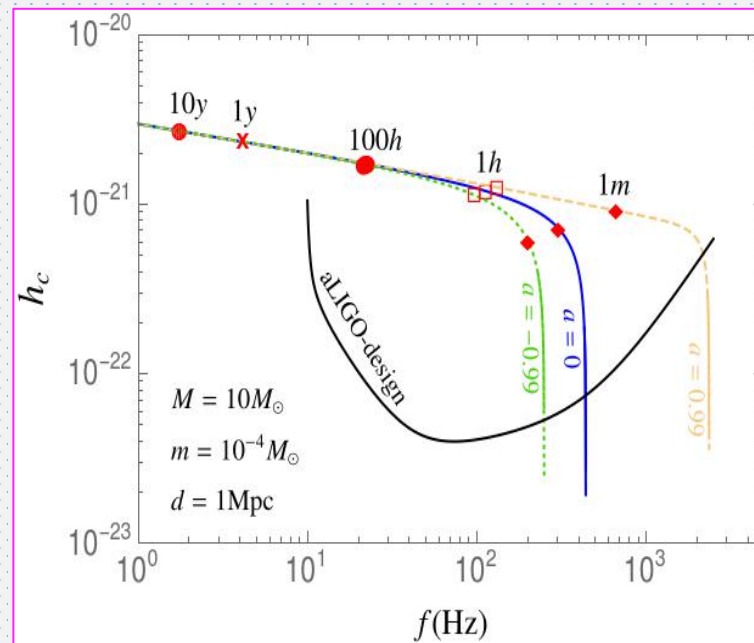
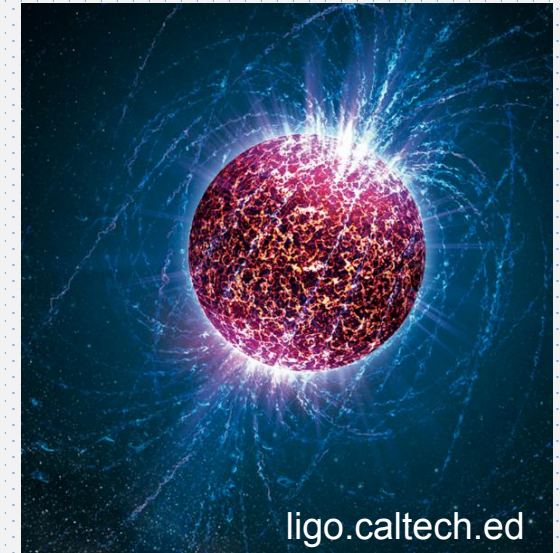
LIGO can detect (non-standard) EMRIs!

Search Strategies

- Signal is similar to continuous waves from neutron stars
- Search strategies can be employed for mini-EMRIs

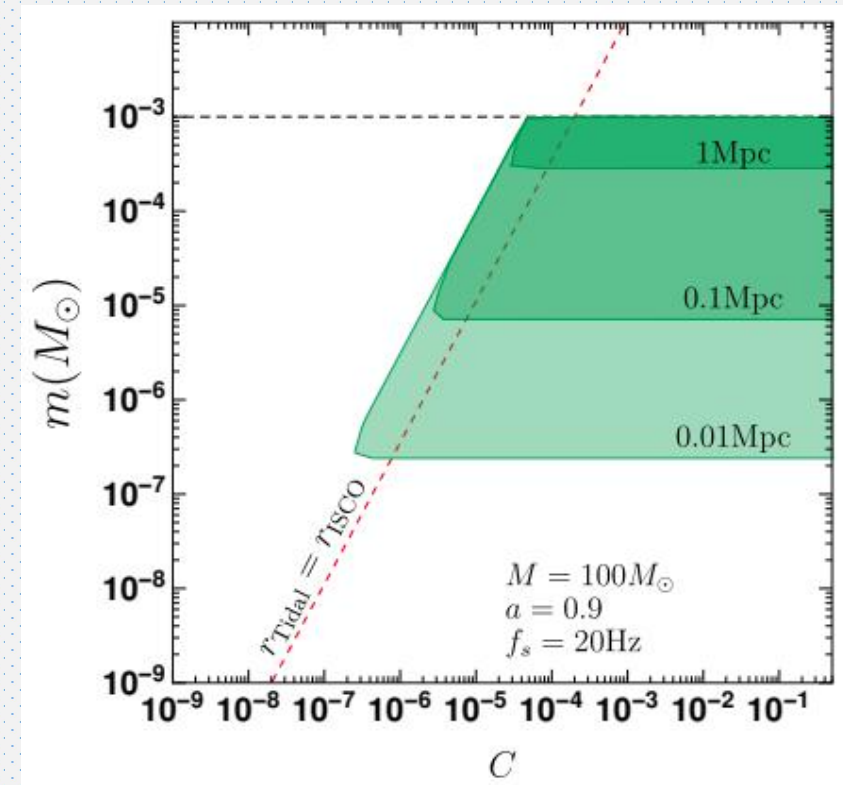
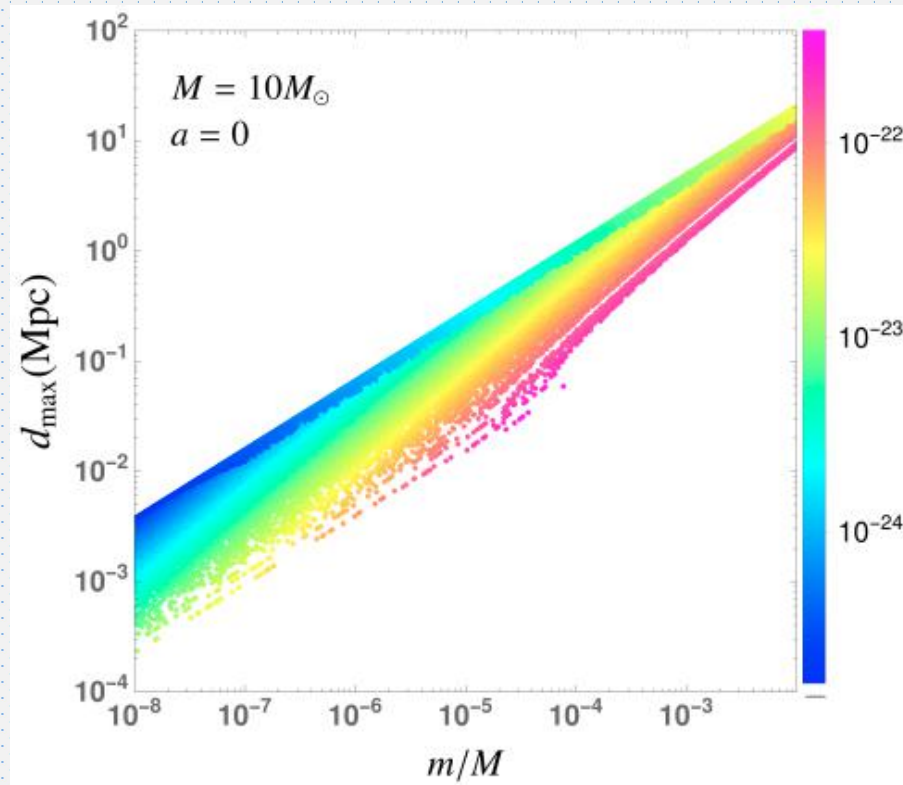


- ✓ **targeted** searches (known black holes, neutron stars as the heavier object)
- ✓ **directed** searches (where their presence is more likely)
- ✓ **all-sky** searches (blind searches)



mini-EMRI Sensitivity to ECOs

- Results obtained with the continuous-wave detection method (Keith, LRR [2206.06447])



HG, A. Miller [2205.10359]

Summary

- EMRIs are ideal systems for searches of subsolar ECOs
- LIGO can detect mini-EMRIs
- mini-EMRIs allow searching for much lighter (subsolar) ECOs
- mini-EMRIs discoverable up to $O(\text{kpc} - 10\text{Mpc})$

Thanks!