

Novel Manifestations of Primordial Black Holes

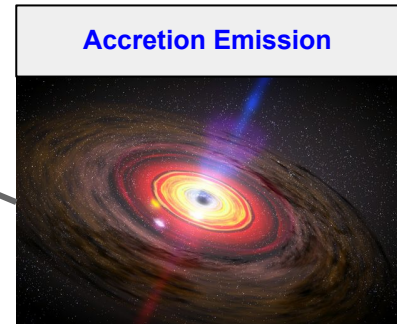
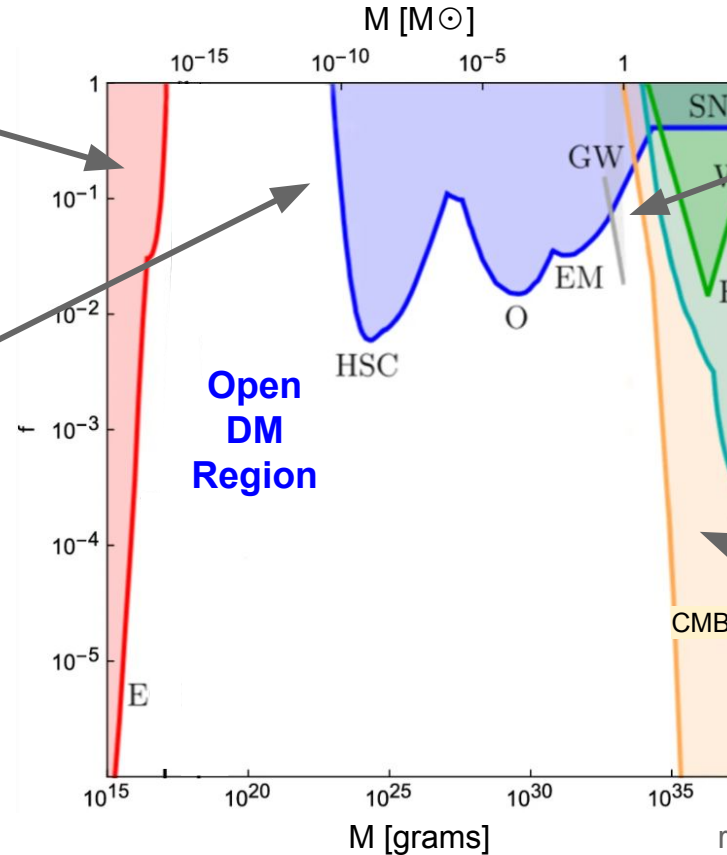
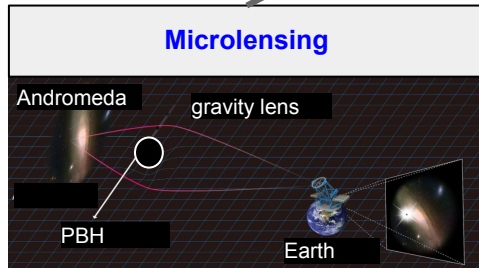
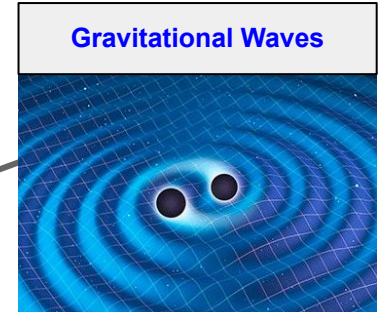
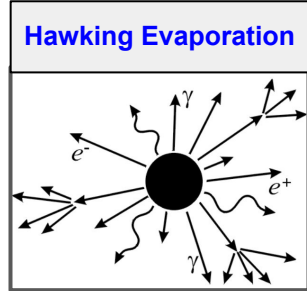
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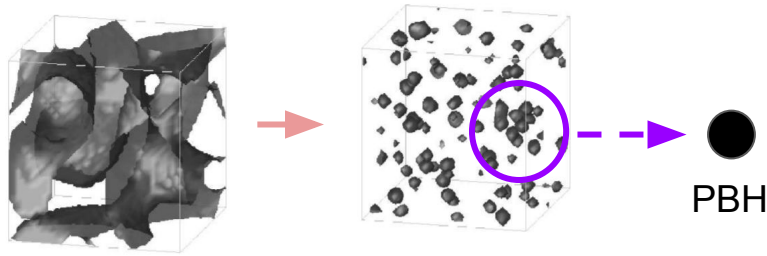


Status



Scenarios Lead to Distinct PBH Features

scalar fragmentation

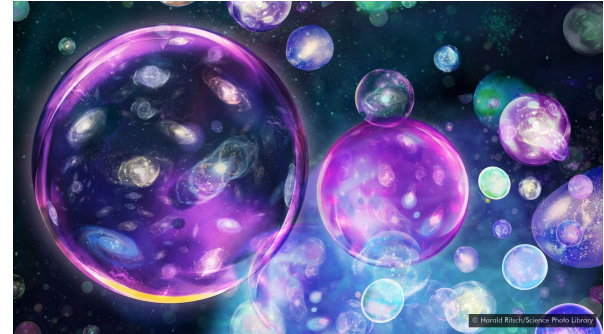


**PBHs peaked in mass
+ big spin possible**

oscillons from inflaton

[Cotner, Kusenko, **Takhistov**, *PRD*, 1801.03321;
Cotner, Kusenko, Sasaki, **Takhistov**, *JCAP*, 1907.10613]

vacuum bubble “multiverse”

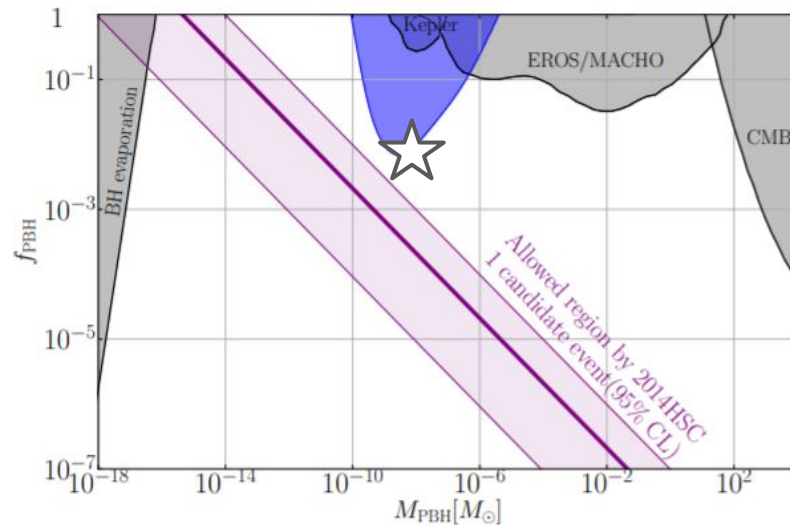
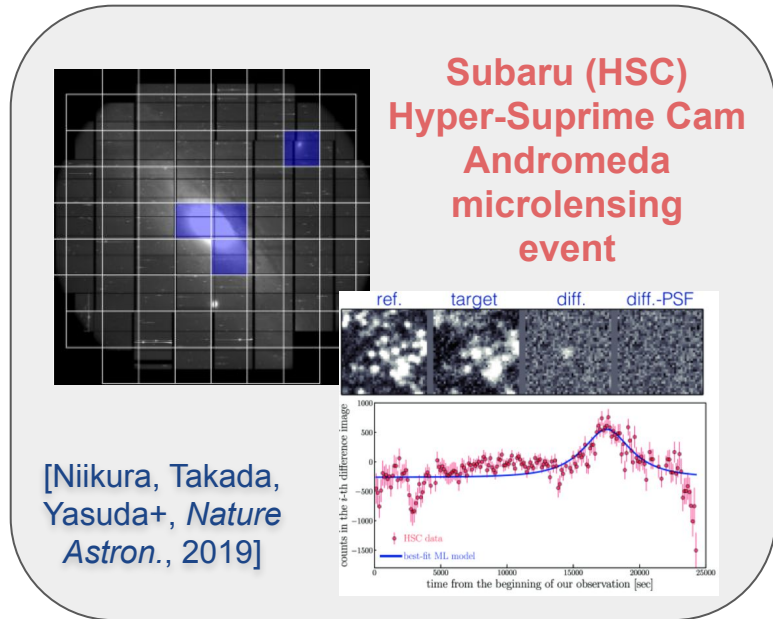


**PBHs broadly
distributed in mass**

[Deng, Vilenkin, Sasaki...;

[Kusenko, Sasaki, Sugiyama, Takada, **Takhistov**,
Vitagliano, *PRL*, 2001.09160]

PBH DM from Bubble Multiverse: Detected by HSC ?!



- **PBH DM from bubble multiverse consistent with detected HSC event !**

→ *tail of broad PBH distribution allows for indirect test of open DM window*

[Kusenko, Sasaki, Sugiyama, Takada, **Takhistov**, Vitagliano, *PRL*, 2001.09160]

Making Gold with Tiny PBHs

- Origin of heavy elements (gold) major long-standing problem

→ *neutron star mergers great, but enough ?* e.g. [Kobayashi+, 2020]



SEPTEMBER 17, 2020 BY BRIAN KOBERLEIN

Colliding Neutron Stars Don't Make Enough Gold to Explain What We See in the Universe

TECH EXPLORIST

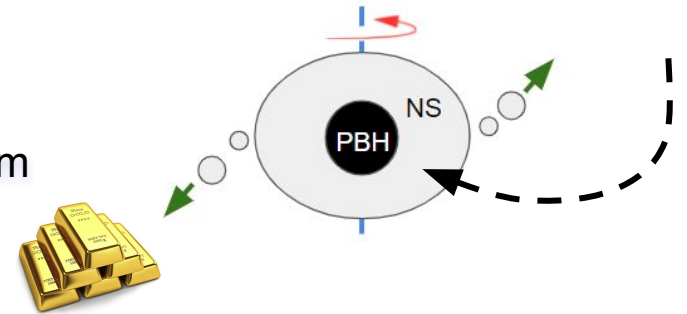
Something is raining gold across the universe

No one knows what it is.

TRENDING

BY AMIT MALEWAR / OCTOBER 3, 2020 / SPACE

- Elegant solution: **asteroid-mass PBHs making DM**
captured by neutron stars, small PBHs eat & explode them
→ “r-process nucleosynthesis” factories



[Fuller, Kusenko, Takhistov, *PRL*, 1704.01129] + Viewpoint Highlight by H.-T. Janka

Neutron Stars (+ White Dwarfs) as PBH Laboratories

“orphan kilonova” without
gravitational waves

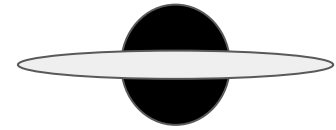


UC Berkeley: Makasdj

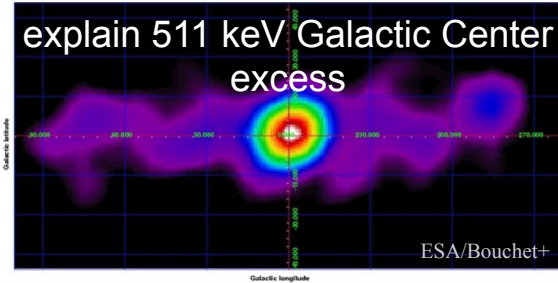
Fast Radio Burst



If **disk + BH** remains →
“orphan Gamma-ray Burst”
without gravitational waves
[Takhistov, *PLB*, 1710.09458]



explain 511 keV Galactic Center
excess

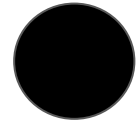
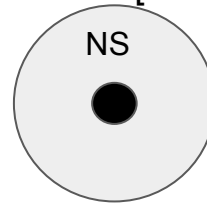


ESA/Bouchet+

*** can explain with regular NS-NS

[Fuller, Kusenko, Radice, Takhistov,
PRL, 1811.00133]

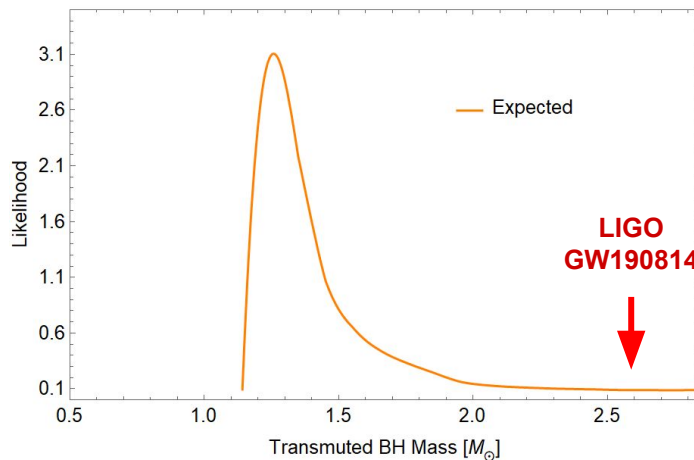
“Transmuted” population of solar-mass BHs
[Takhistov, *PLB*, 1707.05849]



[Fuller, Kusenko, Takhistov, *PRL*, 1704.01129; Takhistov, *PLB*, 1707.05849; Takhistov, *PLB*, 1710.09458]

Origin of Solar-mass Black Holes

- Solar-mass ($\sim 1\text{-}2.5 M_{\odot}$) BHs unexpected in astrophysics \rightarrow PBHs ?
- **LIGO detected candidate event** [Abbott+, *ApJL*, 2020...] ...how to tell BH origin ?
- **Solution:** *transmuted* BHs from PBHs (or particle) DM eating NSs follow NS mass distribution

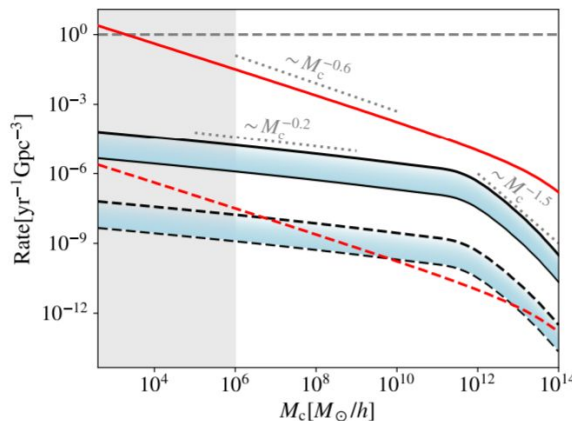
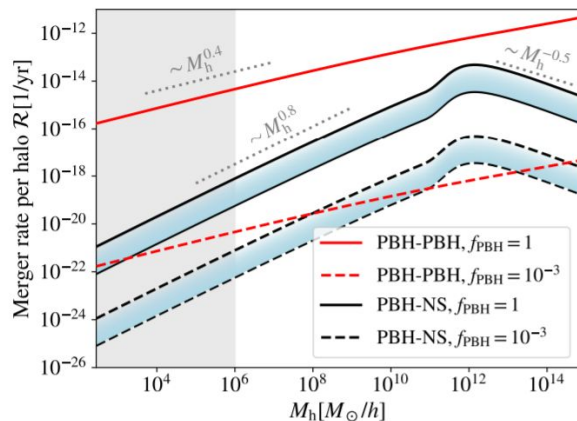


Large ($> 1.5 M_{\odot}$)
candidates unlikely to
be transmuted BHs!

[Takhistov+, *PRL*, 2008.12780]

Identifying Black Hole - Neutron Star (BH-NS) Mergers

- PBH-PBH been linked with LIGO BH-BH GW events [Sasaki, Byrnes, Riotto, Kamionkowski...]
- **First reported BH-NS candidates by LIGO** [Abbott+, *ApJL*, 2021...]from PBHs?
- Unlike PBH-PBH, PBH-NS can only form after star formation



PBH-NS rates subdominant

→ **NS-BH are astrophysical**

*** even if PBH-PBH significant**

[Sasaki, Takhistov, Vardanyan, Zhang, *ApJ*, 2110.09509]

Are Intermediate-mass BHs Primordial ?

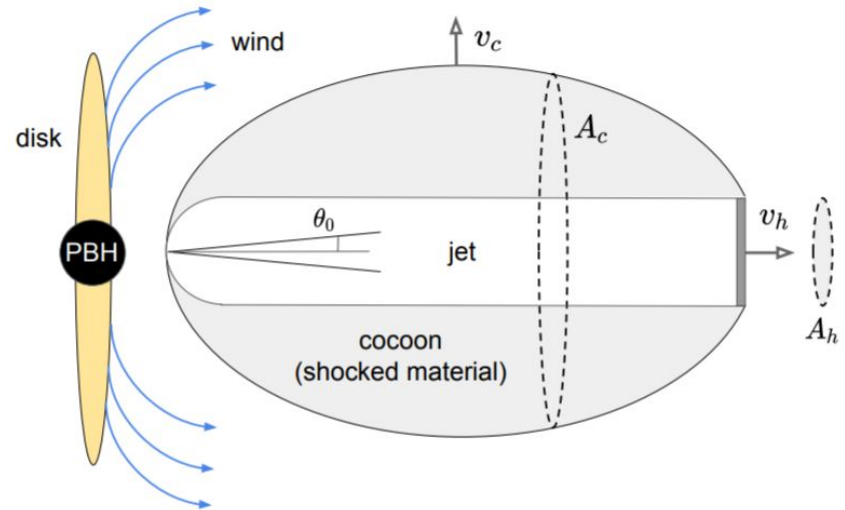
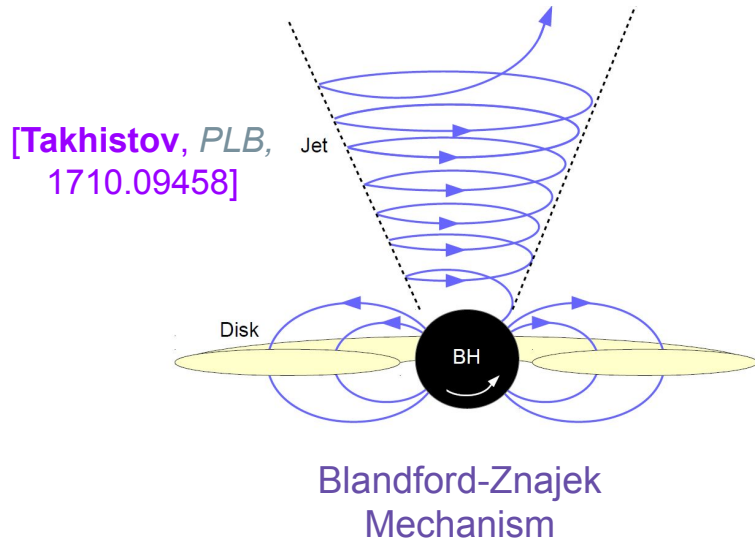
- GW190521 event $\sim 150 M_{\odot}$ merger mass [Abbott+, *PRL*, 2020], first definitive IMBH detection
- **New general cosmology-independent observable:** interactions and **heating** of gas
- Gas heating mechanisms:
 - gravitational drag (dynamical friction)
 - accretion disk photons
 - accretion outflows / winds
- Great testing site: dwarf galaxies (Leo T)



[Lu, Takhistov+, *ApJL*, 2007.02213; Takhistov, Lu+, *JCAP*, 2105.06099]

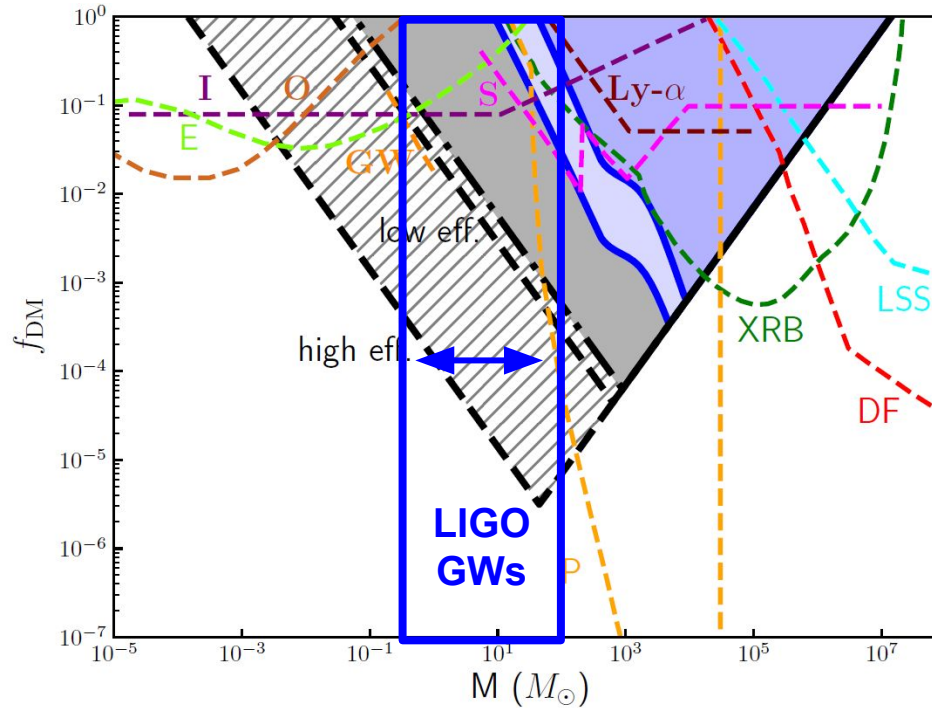
PBH Outflow Winds and Jets

- Outflow winds and powerful jets (especially for spinning PBH) expected to deposit efficiently significant energy via shock heating $L \sim \epsilon \dot{M}$



[Takhistov, Lu, Murase, Inoue, Gelmini, 2111.08699]

PBH Outflow Winds and Jets



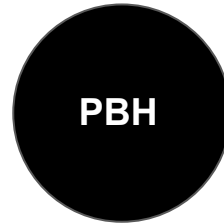
* gas heating from evaporating PBHs

[Laha, Lu, **Takhistov**, *PLB*,
2009.11837]
(also [Kim, 2020])

[**Takhistov**, Lu, Murase, Inoue, Gelmini, 2111.08699]

Summary

- Renaissance era in PBH research
- Strong synergy with observational (especially multi-messenger) astrophysics
- Many new ideas emerging for PBH production, signals, solutions to old puzzles



... Dark Matter ?