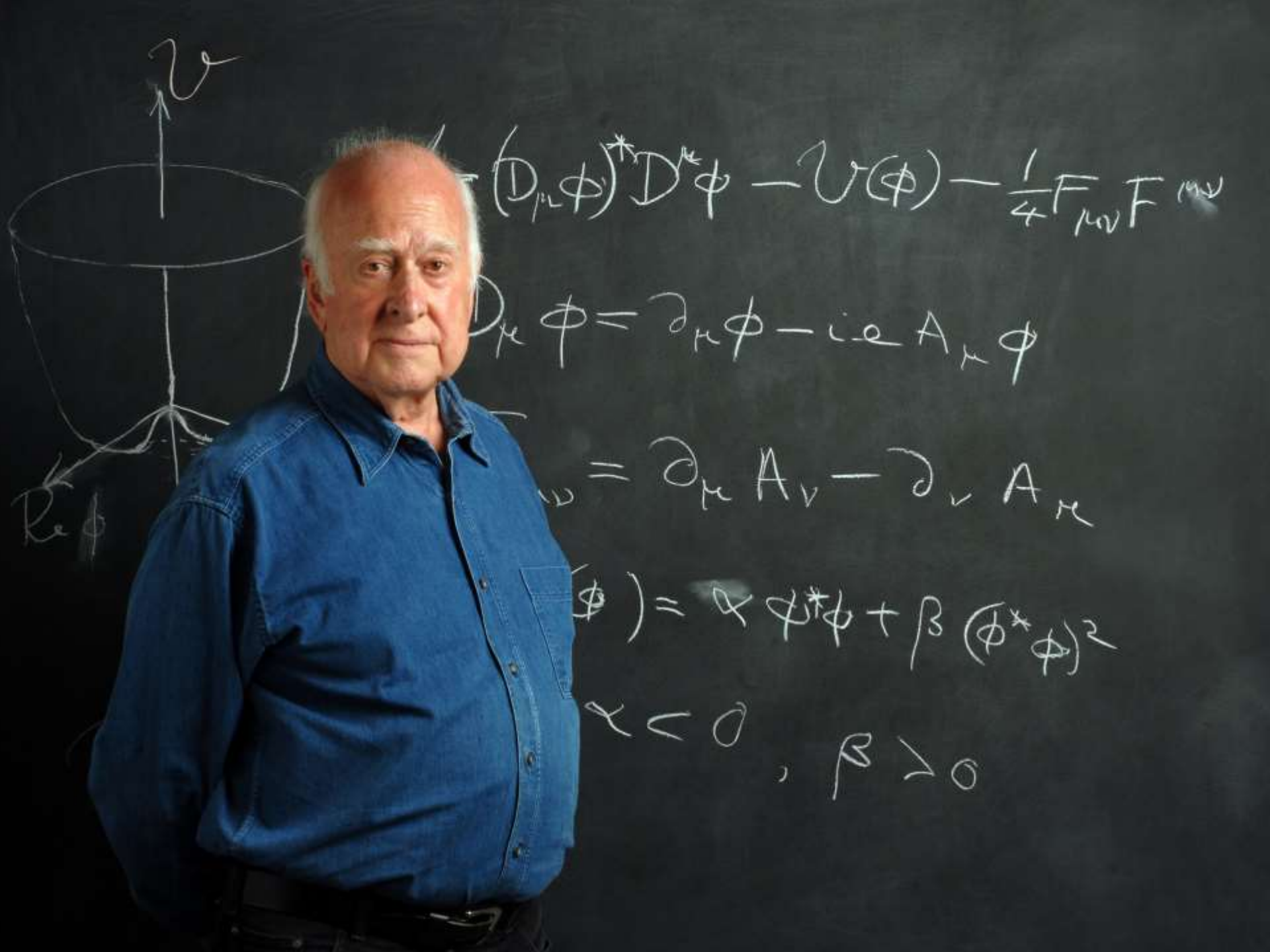
PRESENTATION

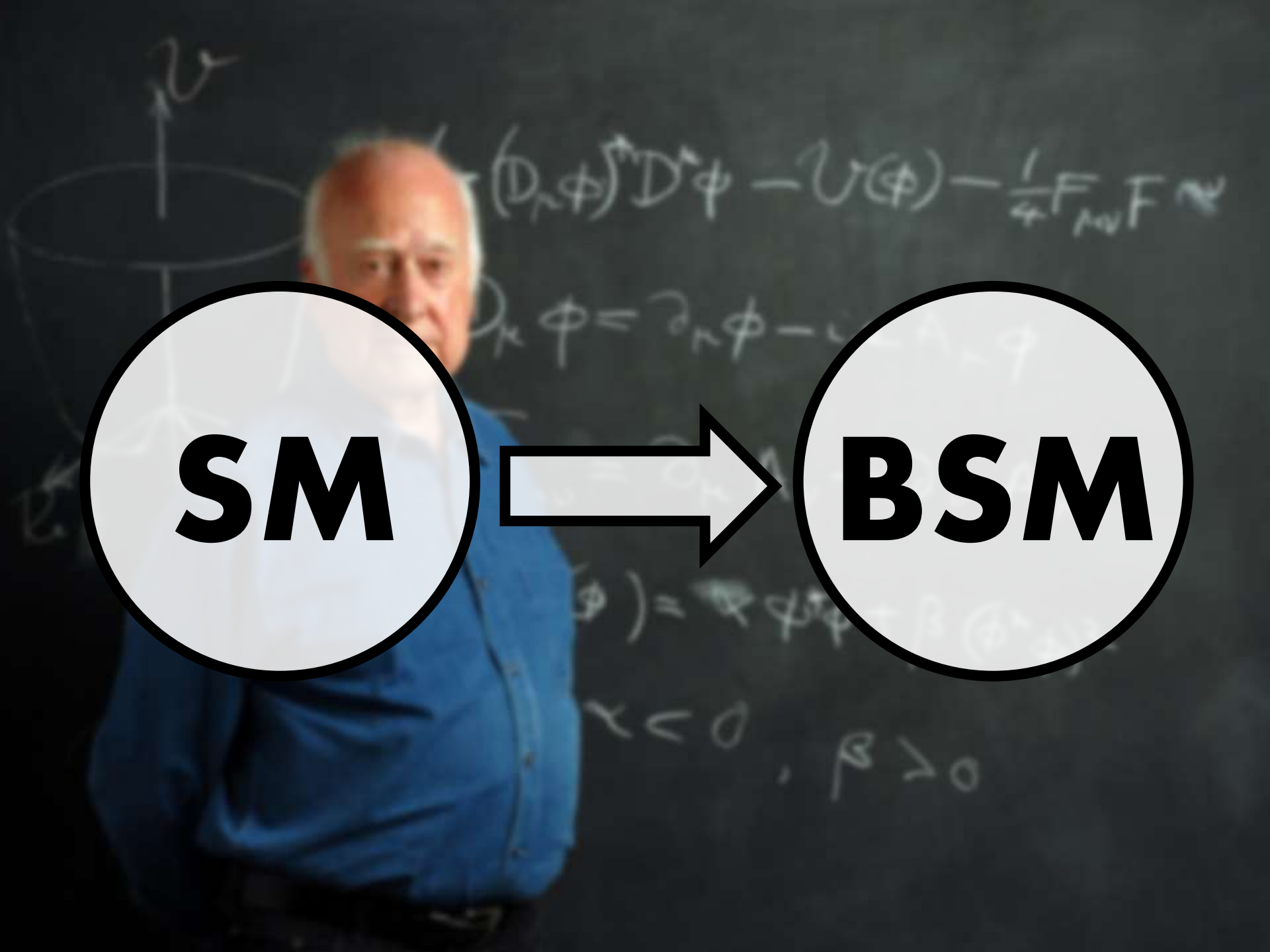
Probing BSM physics via Hawking radiated GW

T.F. & Teruaki Suyama

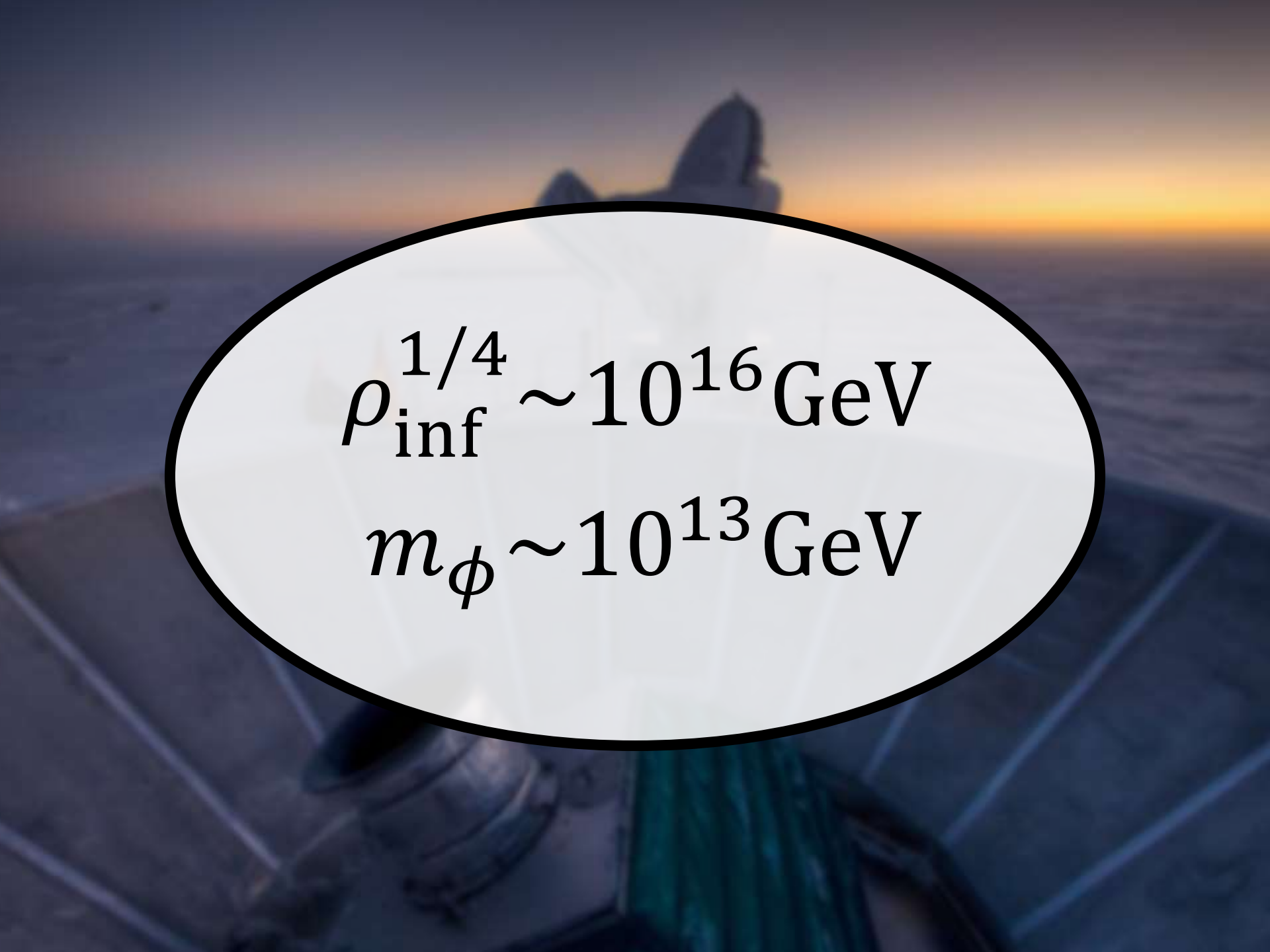
April 17th, 2014 PONT@Avignon

Tokyo Univ./Kavli IPMU Tomohiro Fujita


V
$\mathrm{Re}\,\phi$
$(D_\mu\phi)^* D^\mu\phi - V(\phi) - \frac{1}{4}F_{\mu\nu}F^{\mu\nu}$
$D_\mu\phi = \partial_\mu\phi - ieA_\mu\phi$
$= \partial_\mu A_\nu - \partial_\nu A_\mu$
$\phi) = \alpha\phi^*\phi + \beta(\phi^*\phi)^2$
$\alpha < 0, \ \beta > 0$


SM
BSM


@LHC
No BSM signal



$$\rho_{\mathrm{inf}}^{1/4} \sim 10^{16}\,\mathrm{GeV}$$

$$m_{\phi} \sim 10^{13}\,\mathrm{GeV}$$

We need...

More information about new physics

We need...

Mass spectrum of new physics

We need...

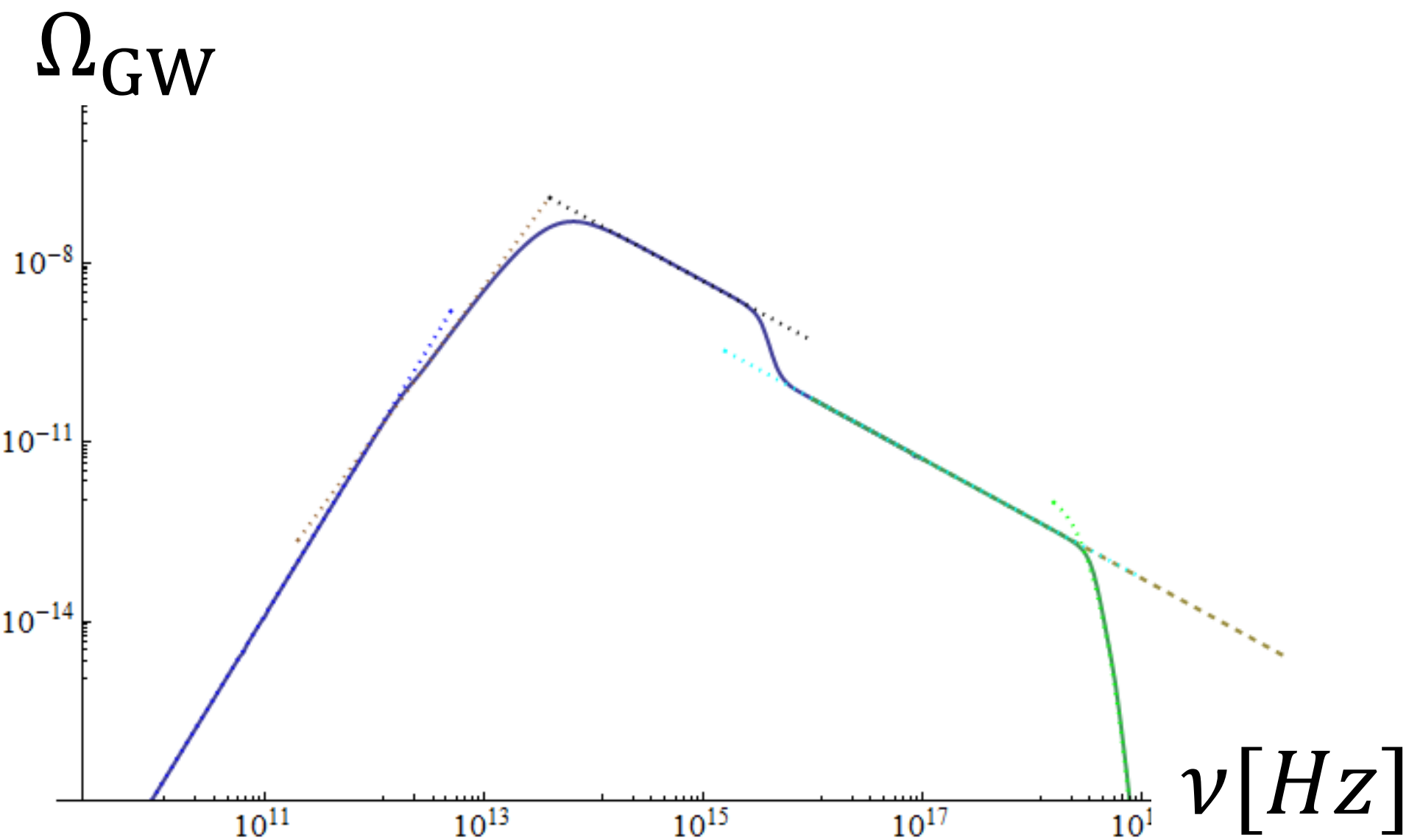
Mass spectrum of new physics

How to know??

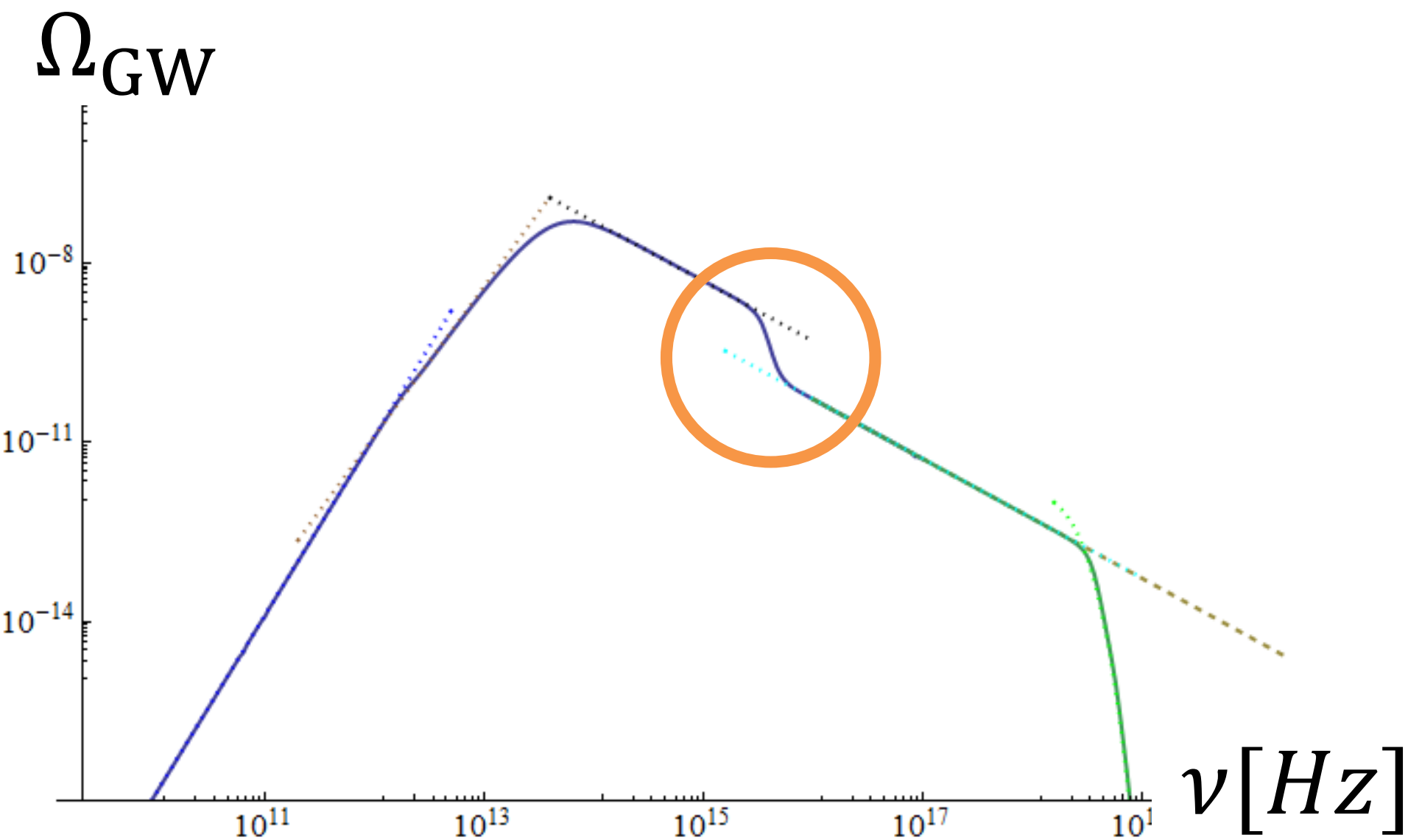
Answer

Observe GW form PBH

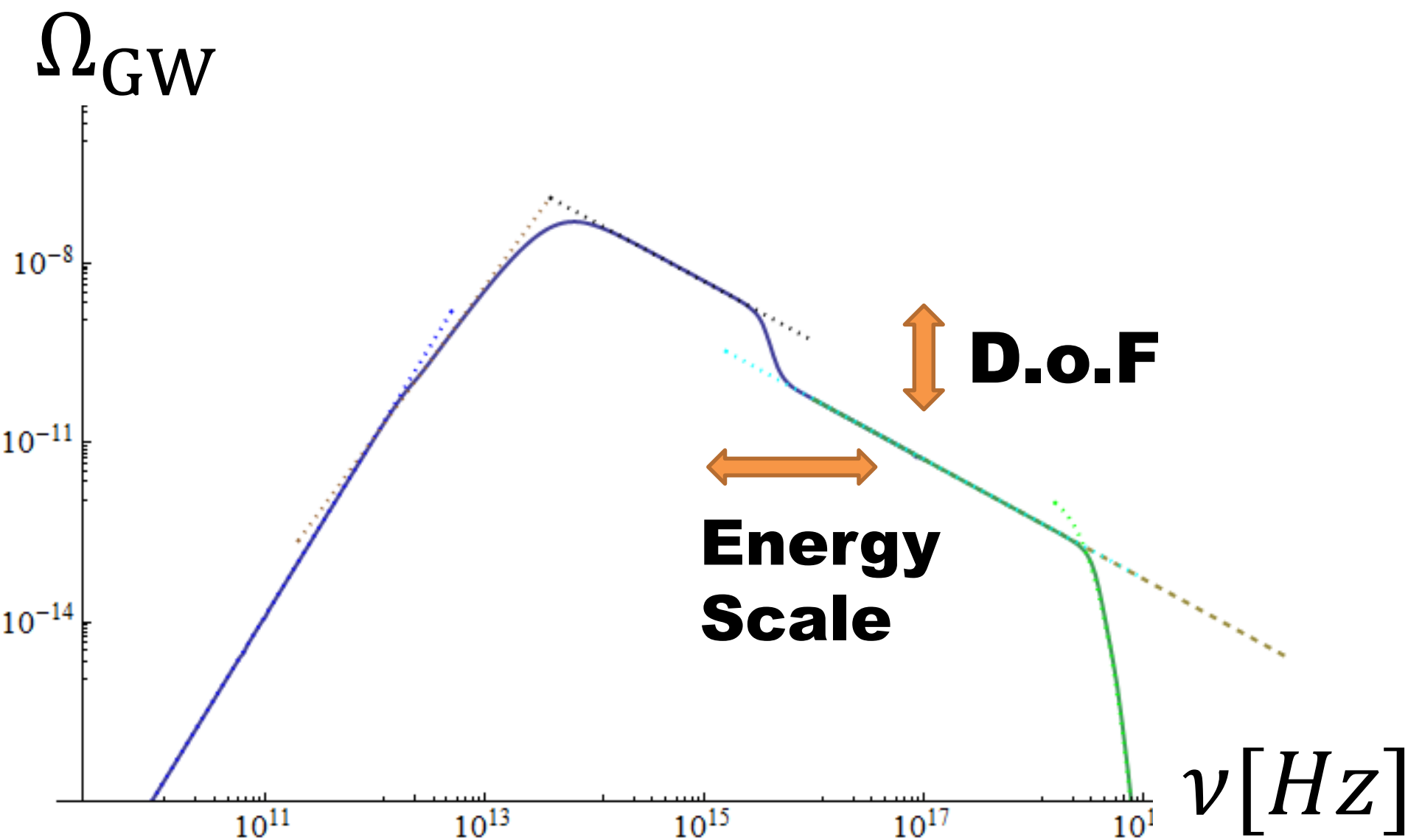
GW spectrum from PBH



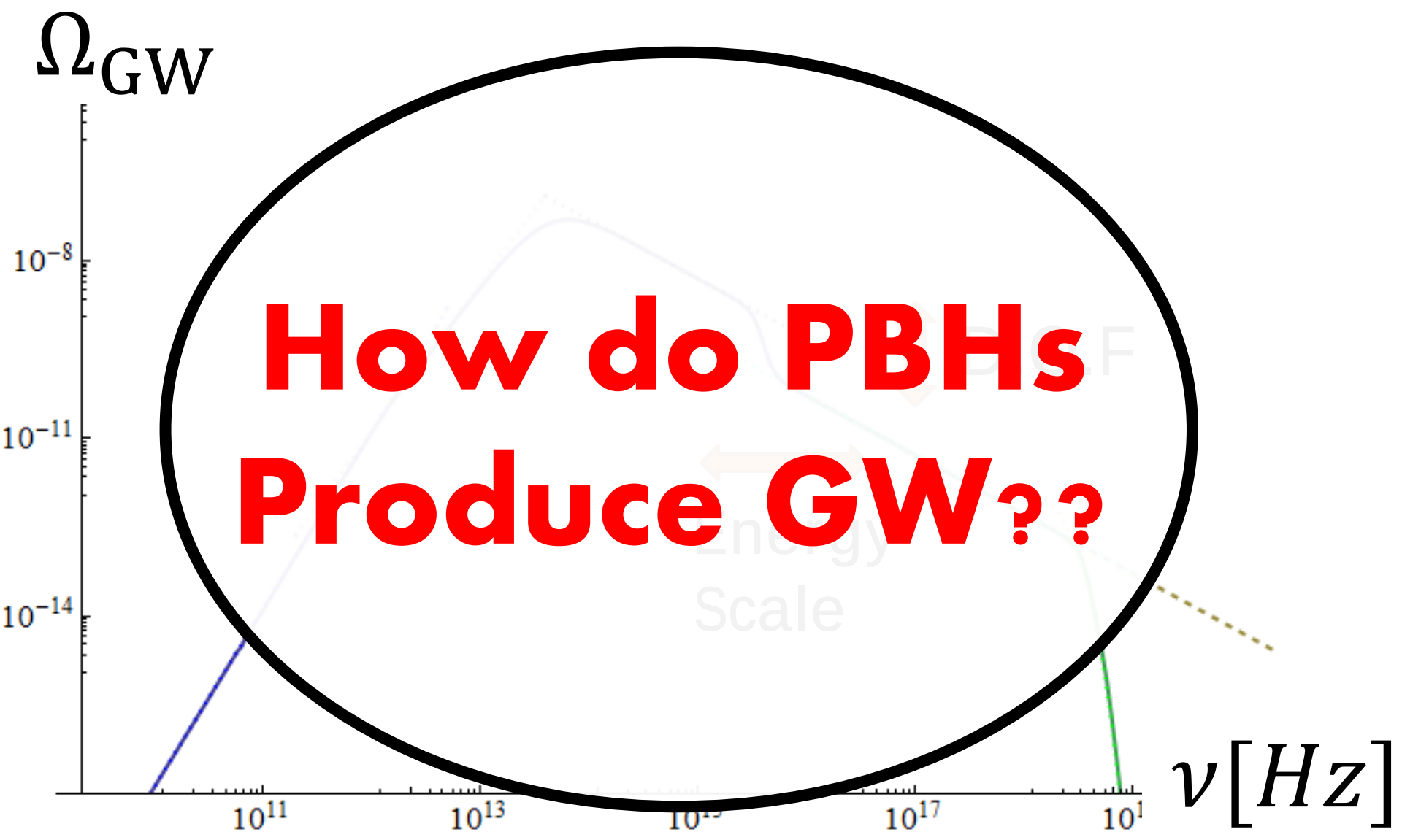
GW spectrum from PBH



GW spectrum from PBH



GW spectrum from PBH



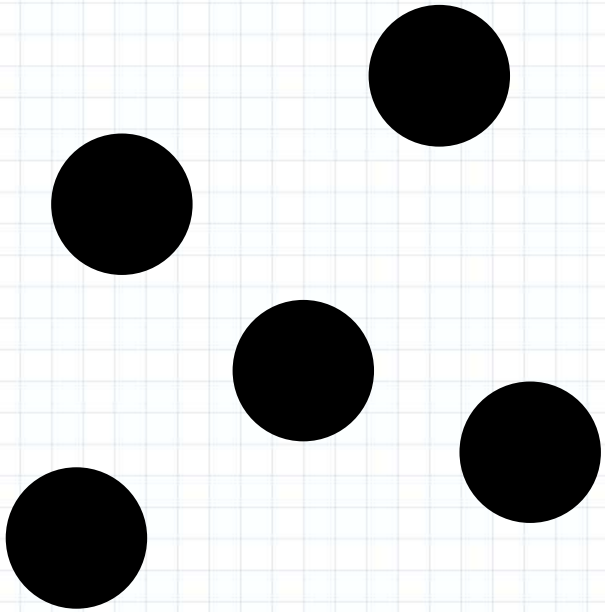
How do PBHs Produce GW??


Hawking radiation

PBH Production

PRESENTATION

[Taruya(1999), Suyama et al.(2005), Hawking et al.(1982), Hogan(1984)], Jedamzik(1997).



PBHs

PBH can form in many scenarios.

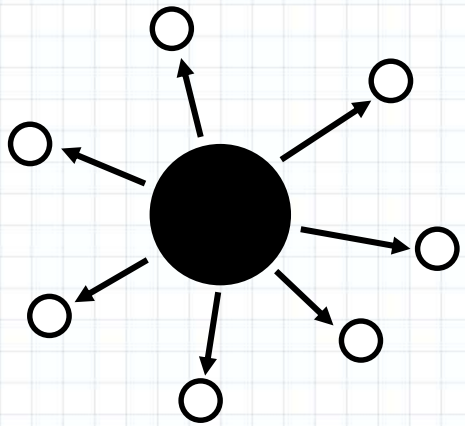
- Inflation
- Preheating
- Bubble collision
- Cosmic string
- Sudden pressure reduction

HR is significant if

$$M_{BH} < 10^{15}\mathrm{g}$$

Hawking radiation

[Hawking(1975)]



Black Hole

≈

Black Body radiator

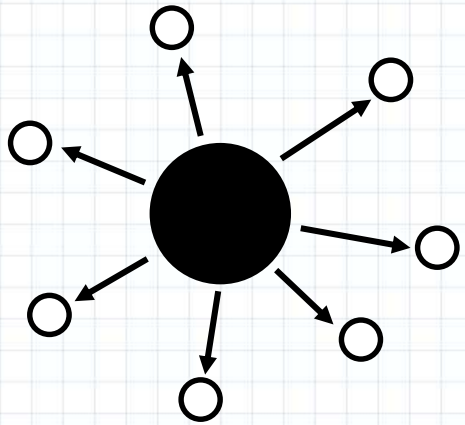
Any particles with

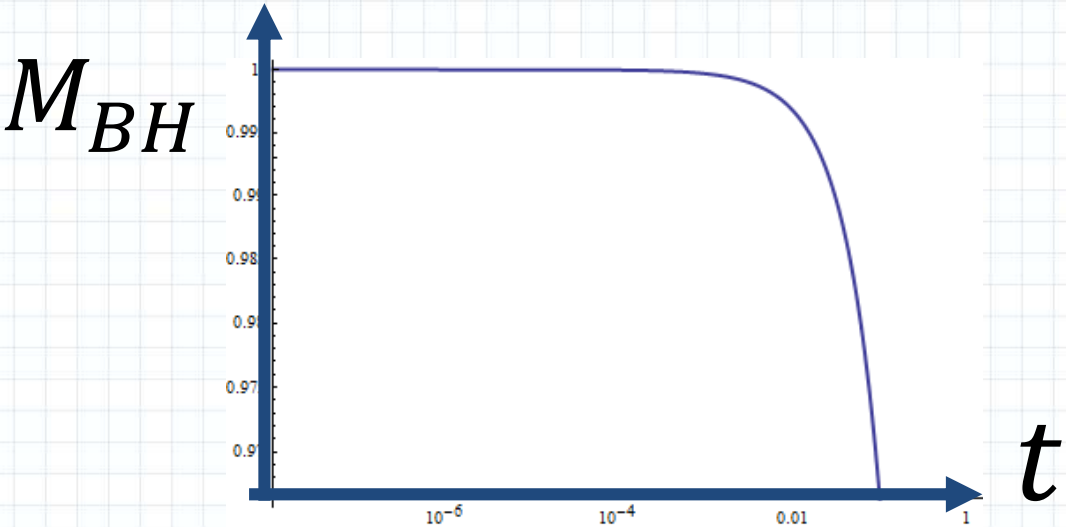
$$m < T_{BH} = \frac{M_{Pl}^2}{M_{BH}}$$

are radiated.

Hawking radiation

PRESENTATION

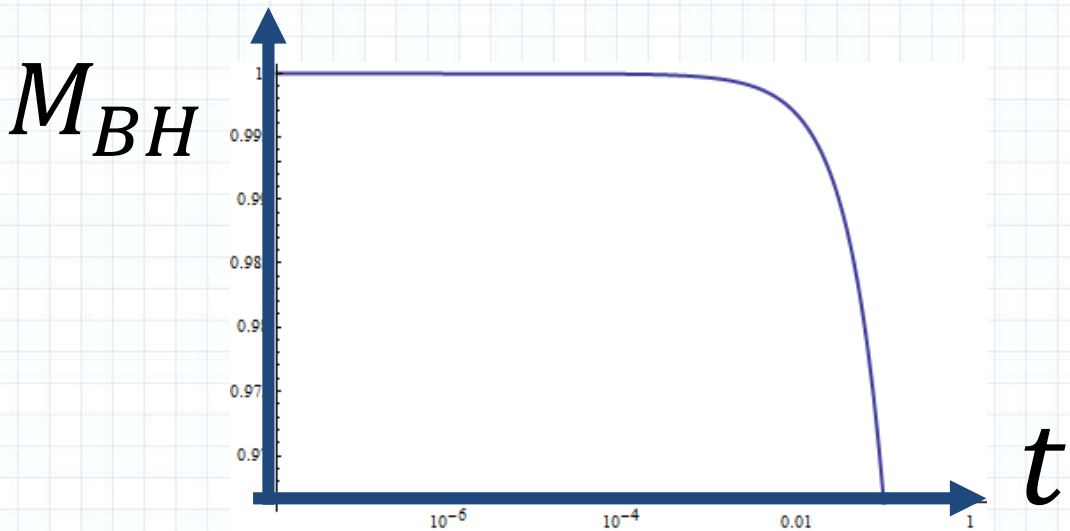


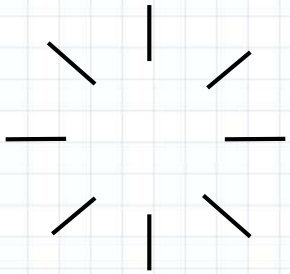


Black Hole

Hawking radiation

PRESENTATION



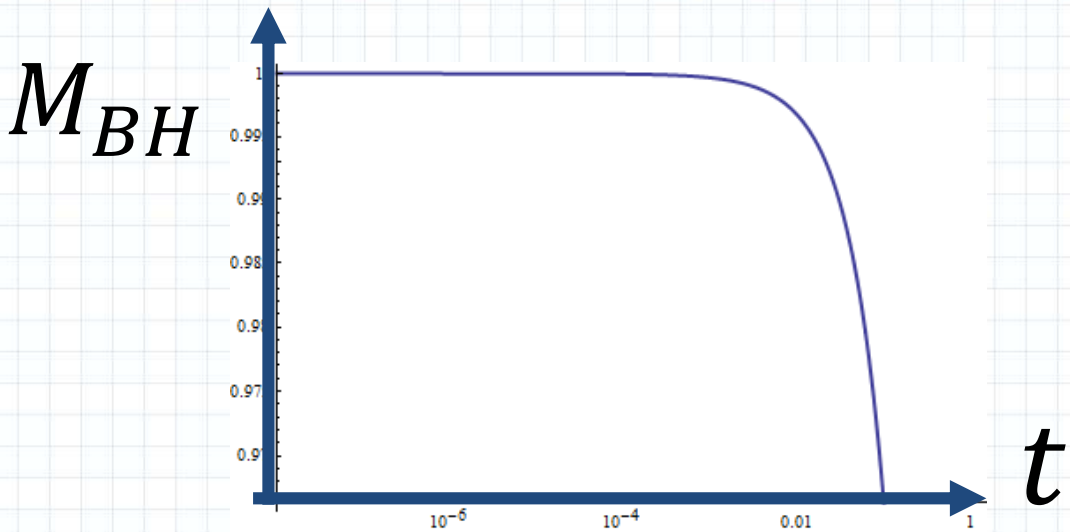


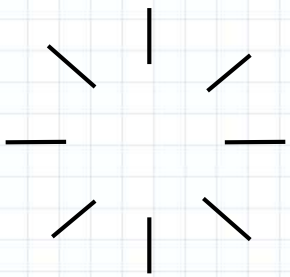
Black Hole

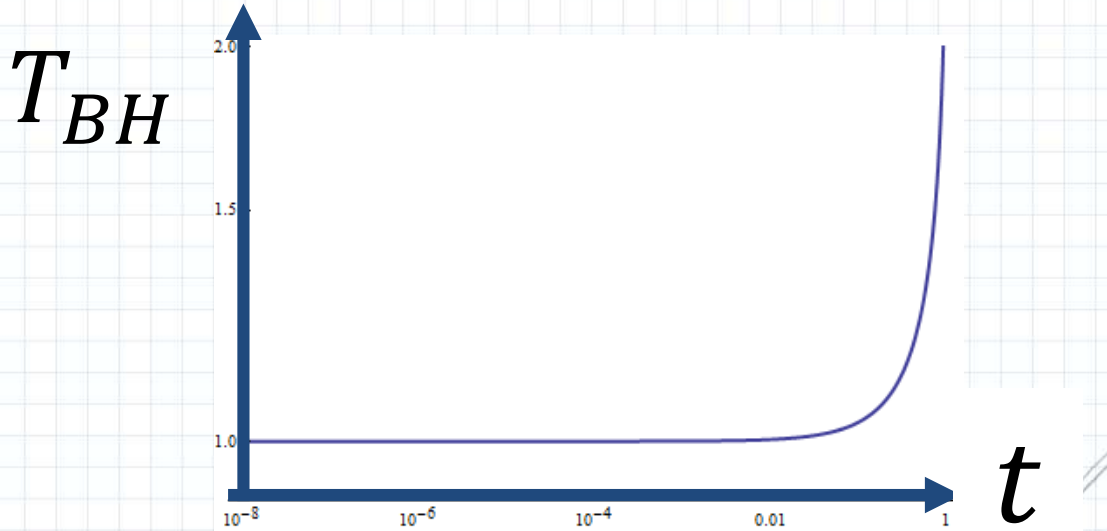
evaporates

Hawking radiation

PRESENTATION







Black Hole

evaporates

Hawking radiation

PRESENTATION

$$\Omega_{GW} \sim \frac{\nu_0^4}{\rho_0} \int_{t_{\text{form}}}^{t_{\text{evap}}} dt \frac{n_{BH} T_{BH}^{-2}}{\exp\left[\frac{2\pi\nu_0/a}{T_{BH}}\right] - 1}$$

Hawking radiation

PRESENTATION

PBH continues to radiate gravitons

a^{-3}

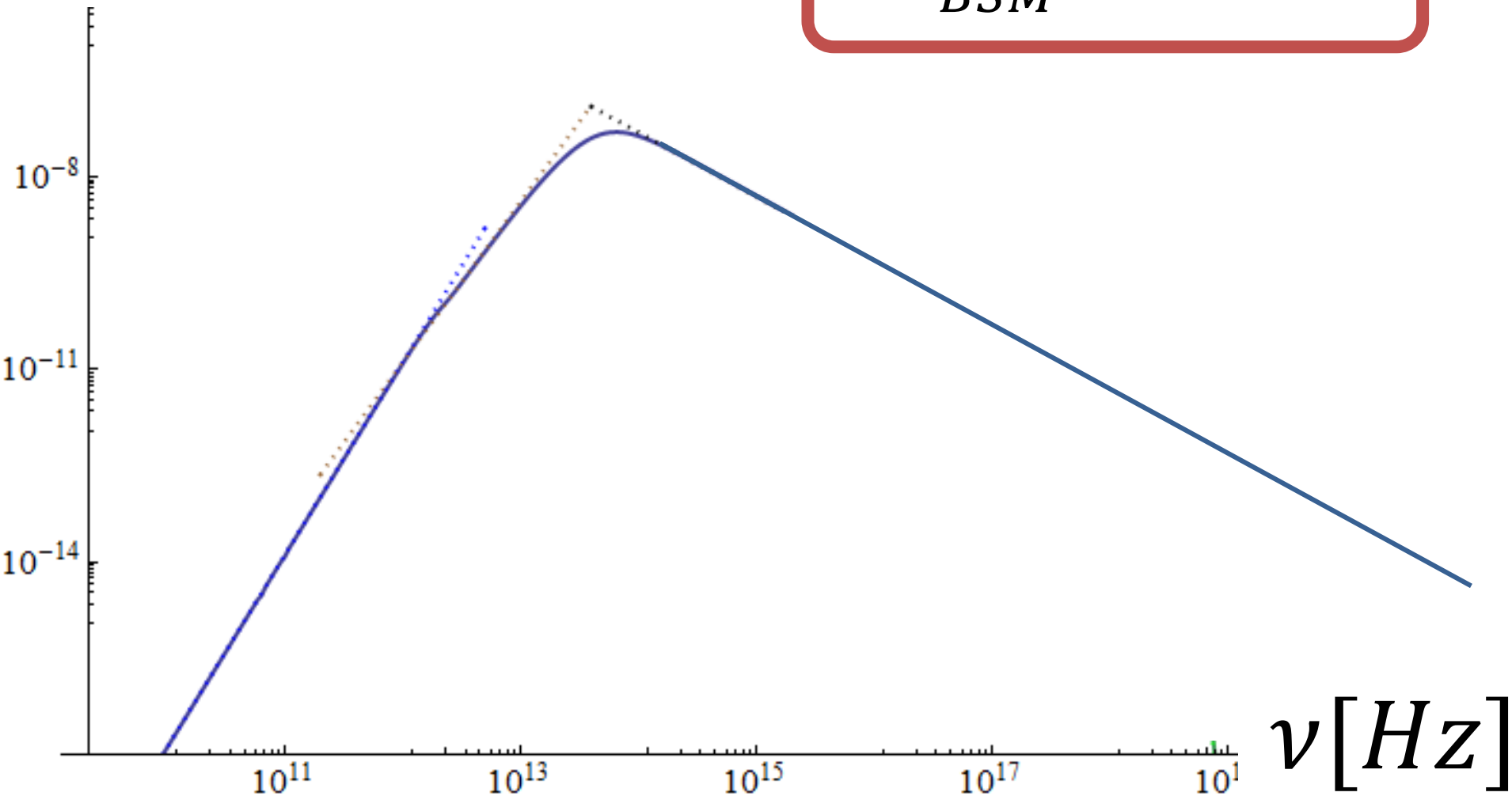
$A_{BH} \propto R_s^2 \propto M_{BH}^2$

$$\Omega_{GW} \sim \frac{\nu_0^4}{\rho_0} \int_{t_{\mathrm{form}}}^{t_{\mathrm{evap}}} dt \frac{n_{BH} T_{BH}^{-2}}{\exp\left[\frac{2\pi\nu_0/a}{T_{BH}}\right] - 1}$$

Graviton with $\nu_0 \sim a T_{BH}(t)$ is emitted.

GW spectrum from PBH

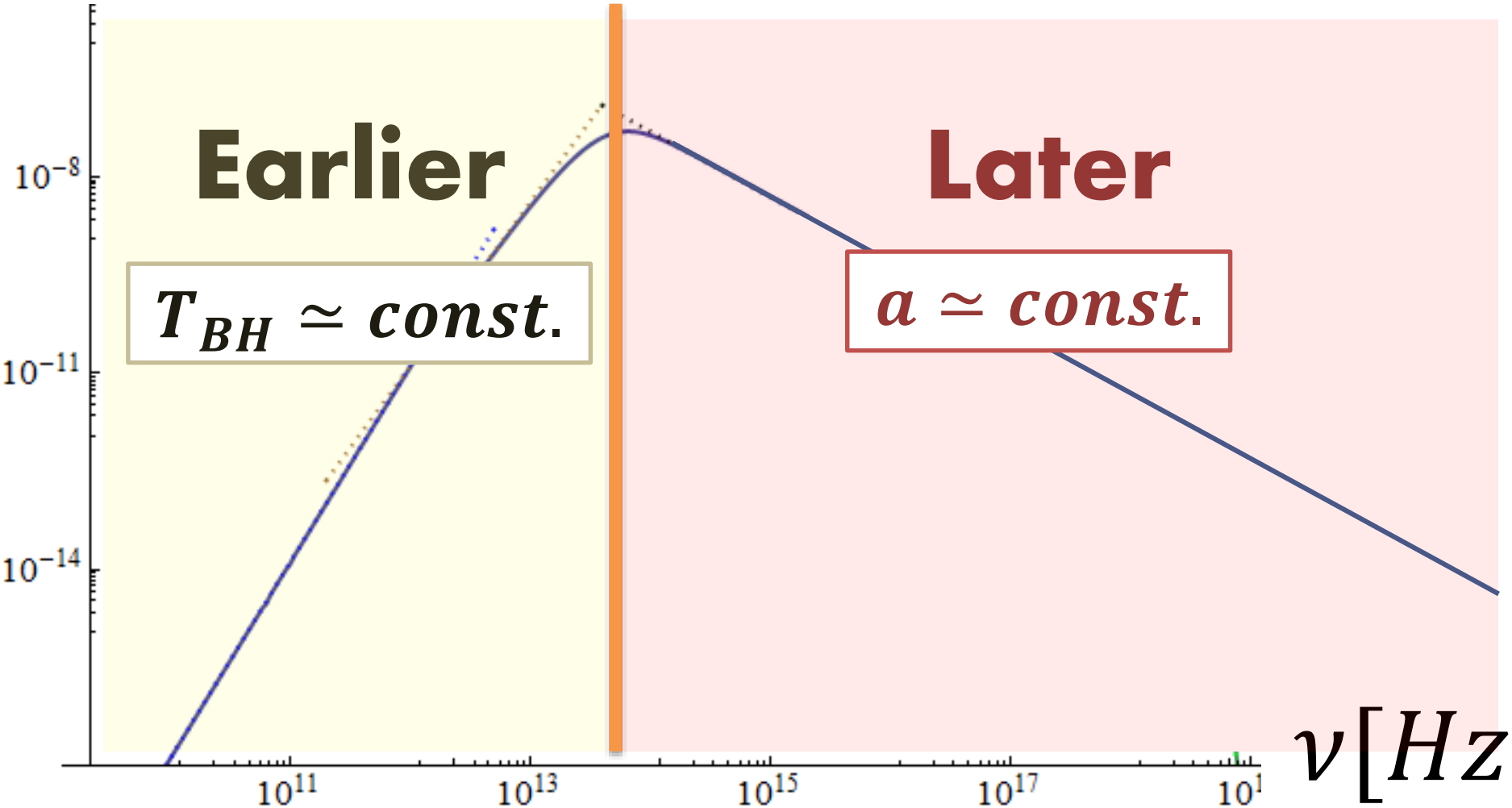
$E_{BSM} = \text{None}$



GW spectrum from PBH

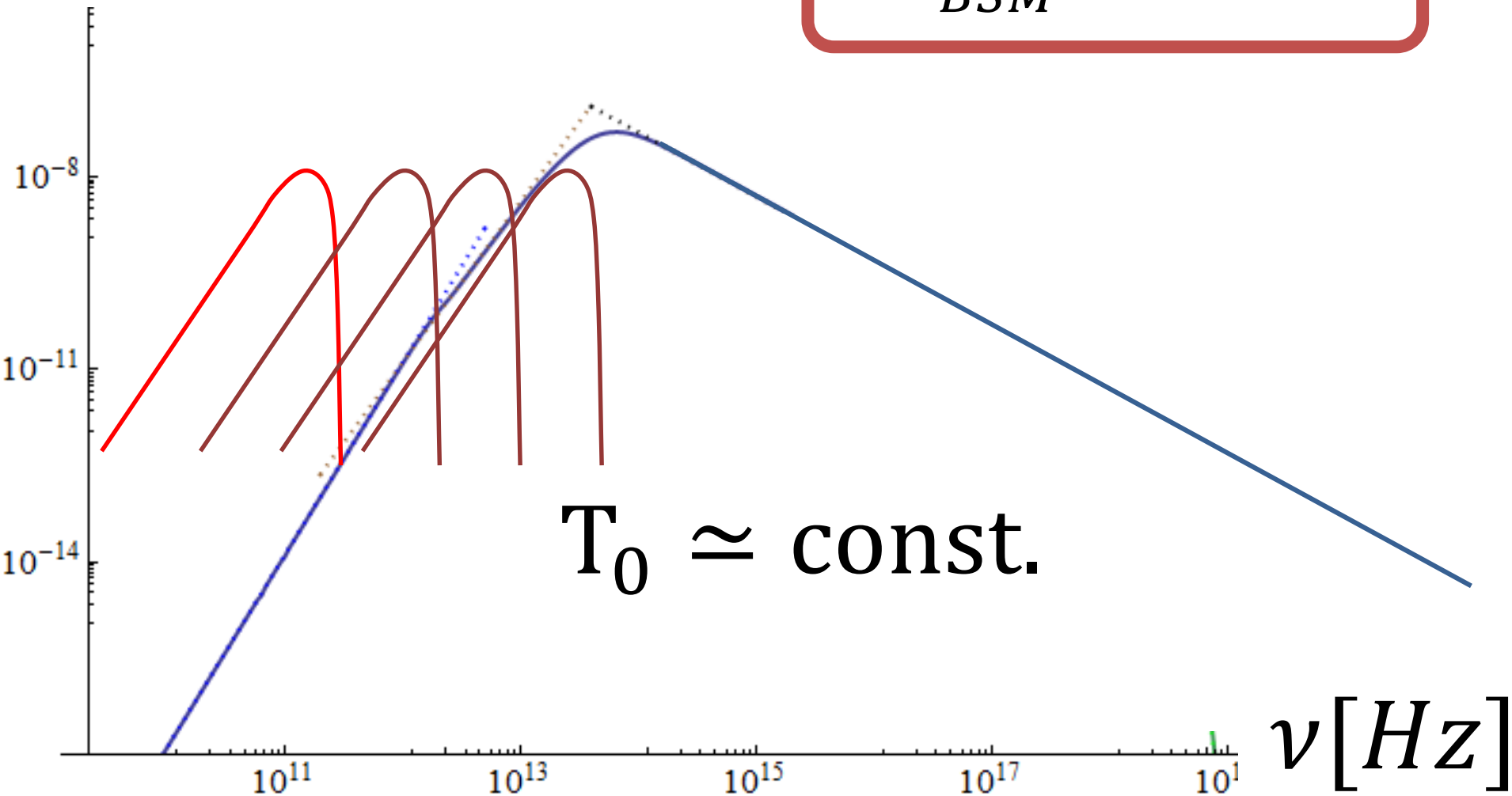
Ω_{GW}

$\nu_0 \sim aT_{BH}(t)$



GW spectrum from PBH

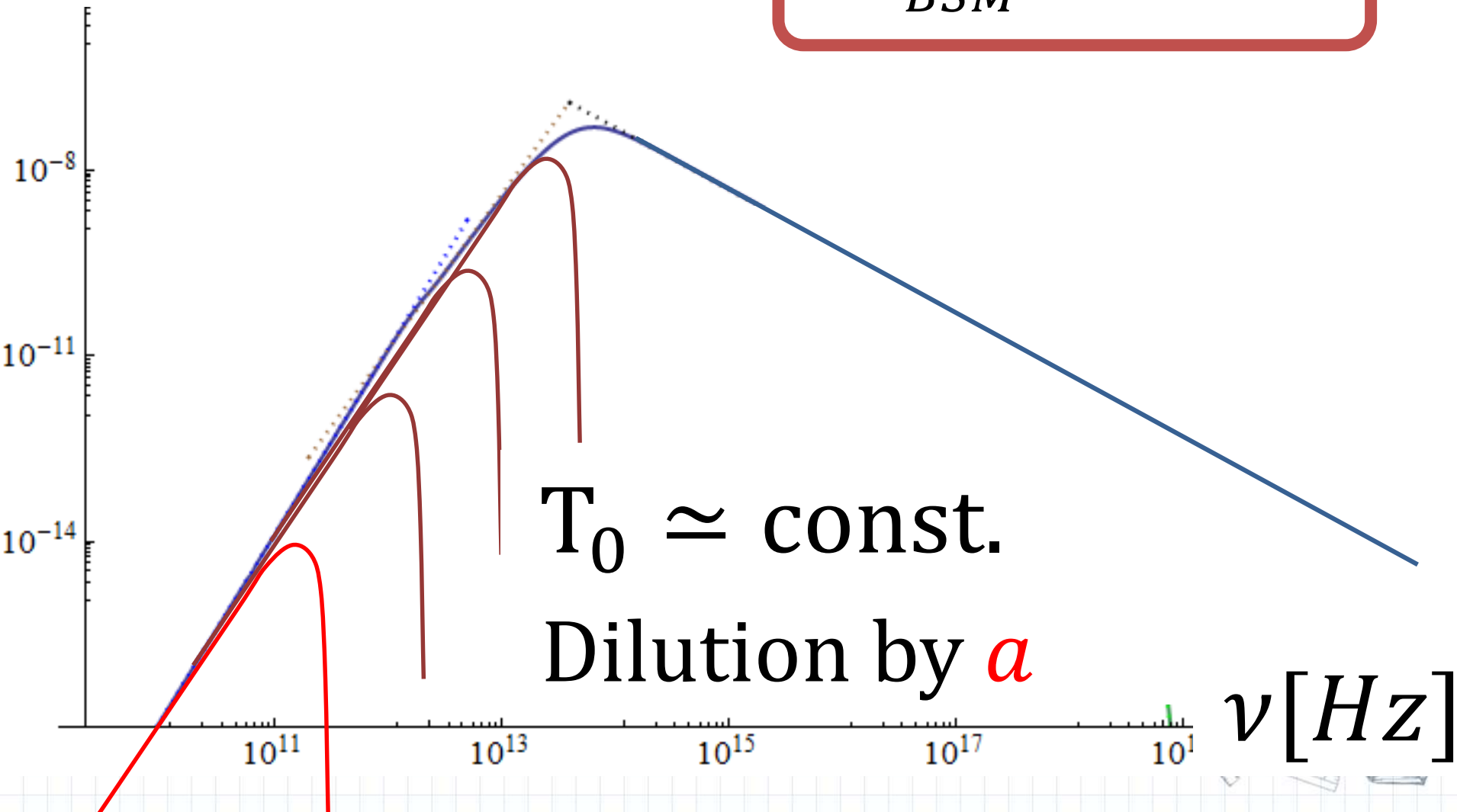
$E_{BSM} = \text{None}$



$T_0 \simeq \text{const.}$

GW spectrum from PBH

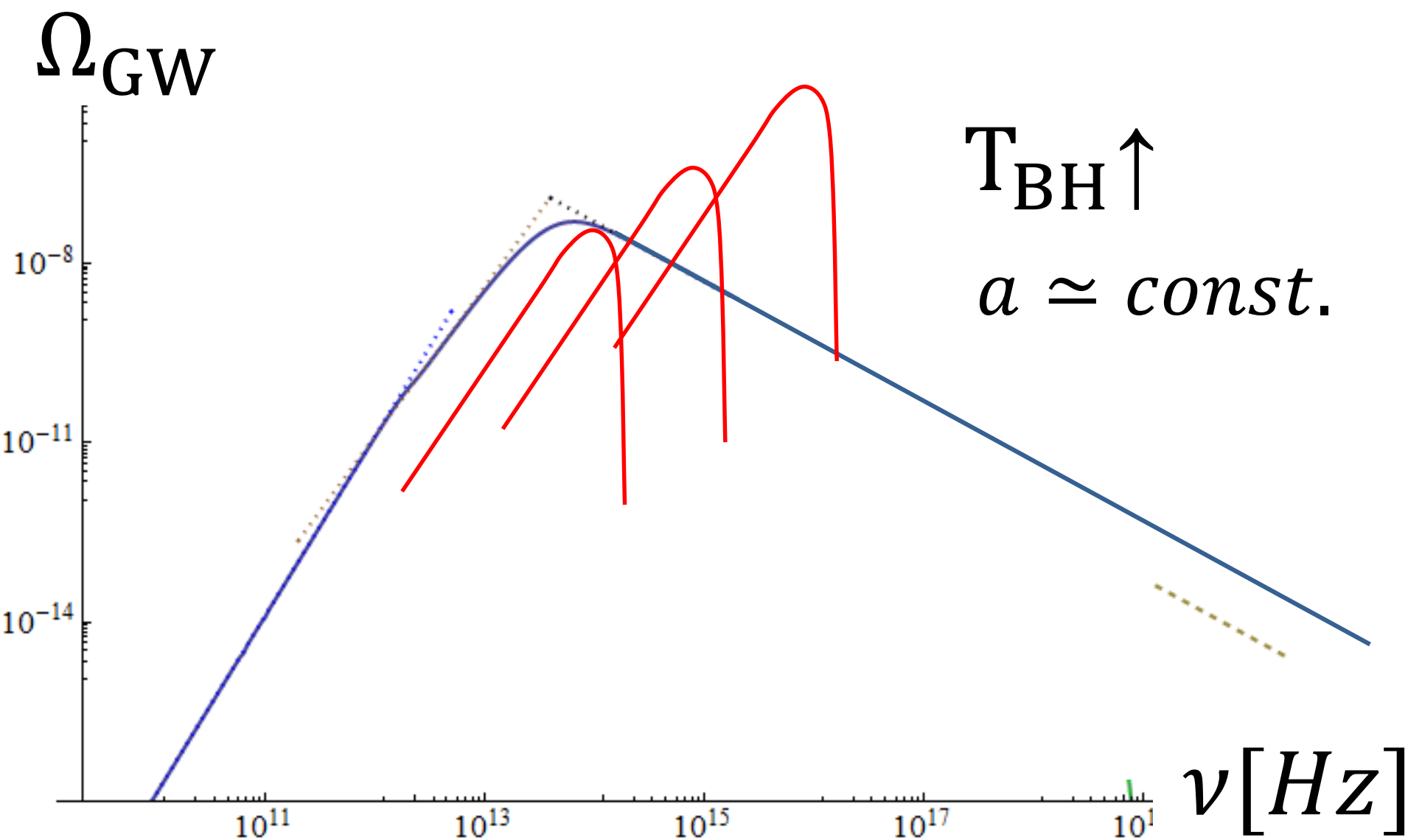
$E_{BSM} = \text{None}$



$T_0 \simeq \text{const.}$

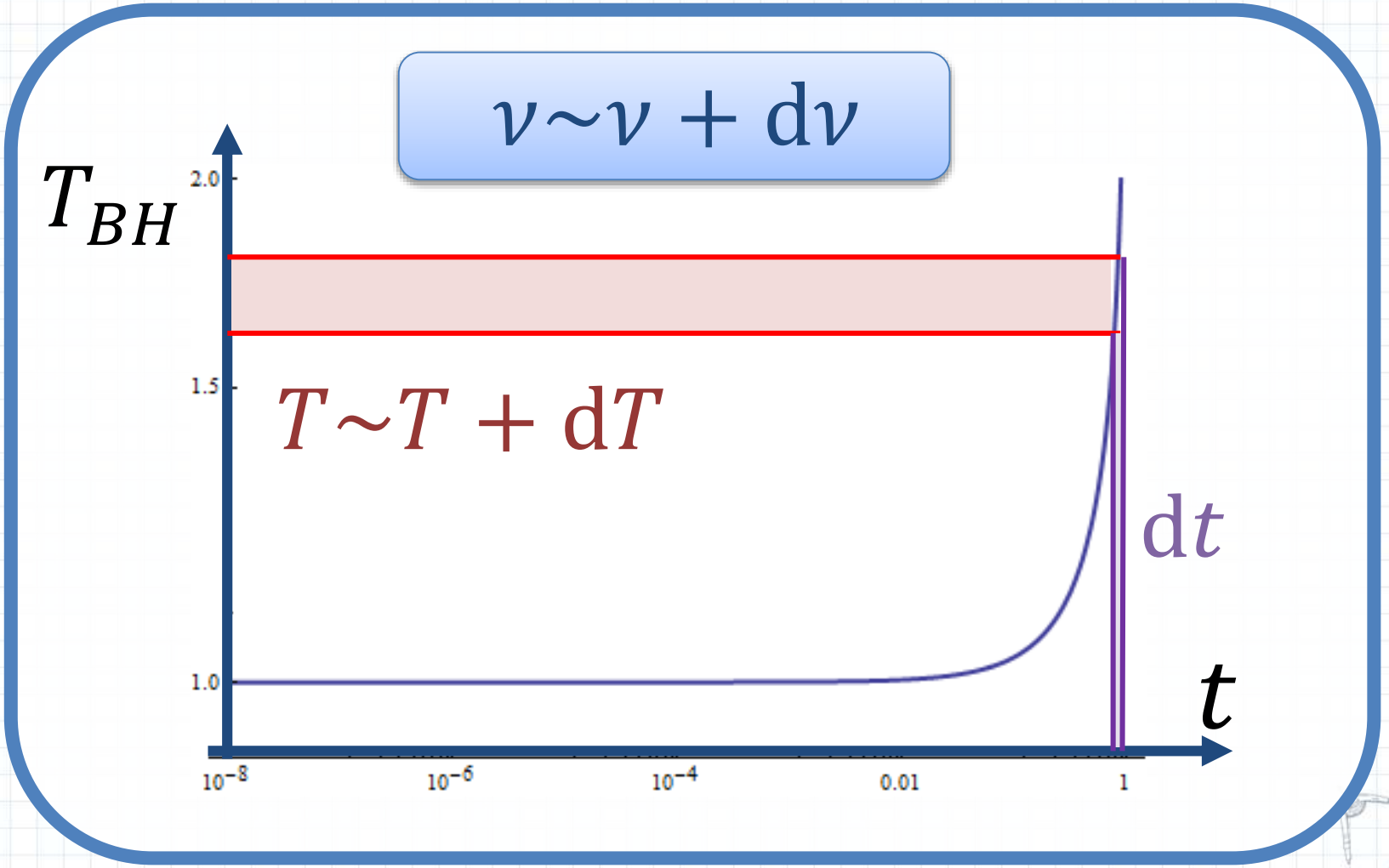
Dilution by a

GW spectrum from PBH

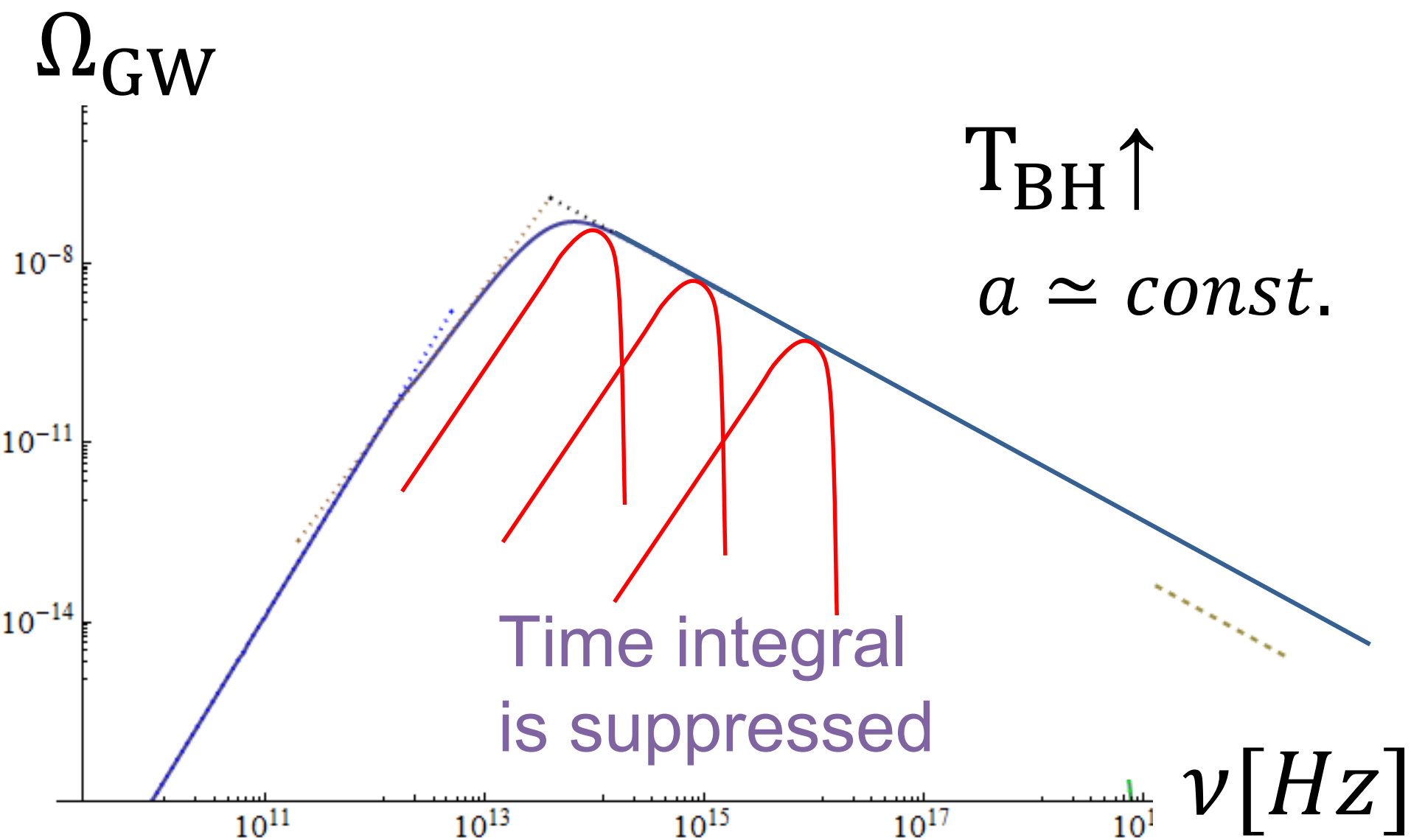


GW spectrum from PBH

PRESENTATION



GW spectrum from PBH



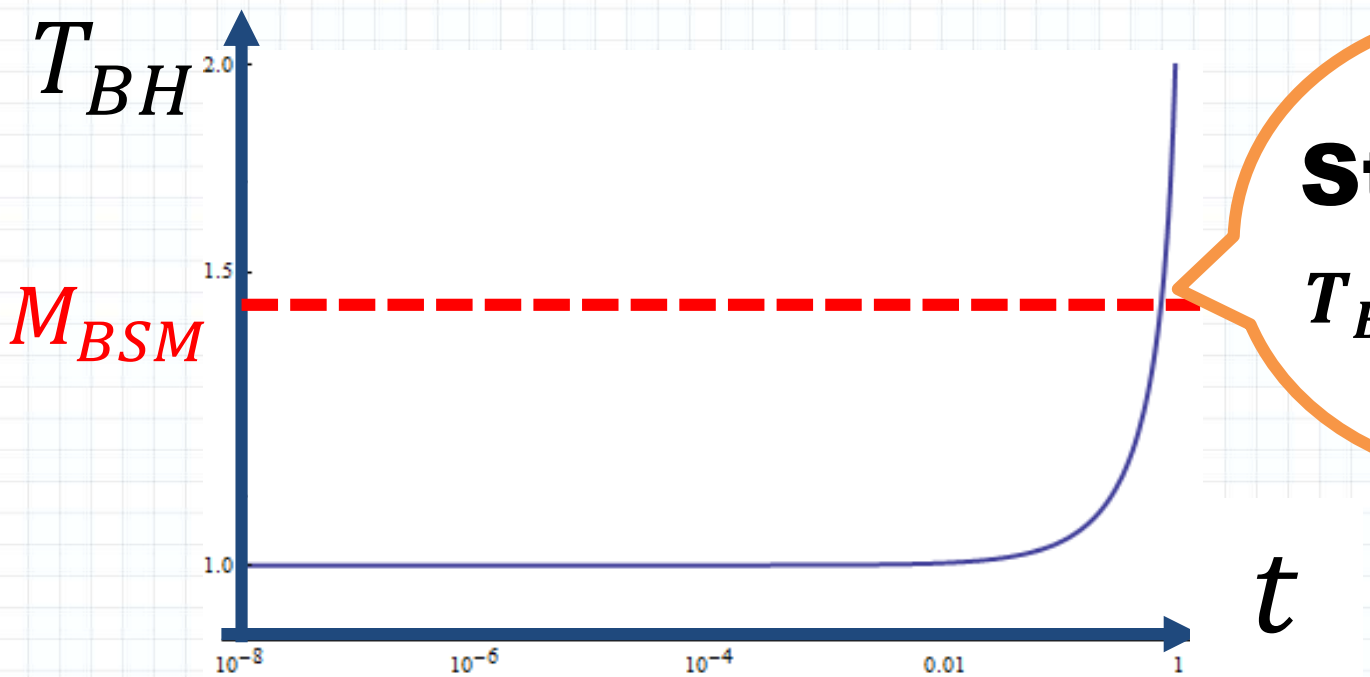

Why Step?

Why step in GW spectrum?

PRESENT

If massive particles exist,

$$M_{BSM} \gg T_0$$



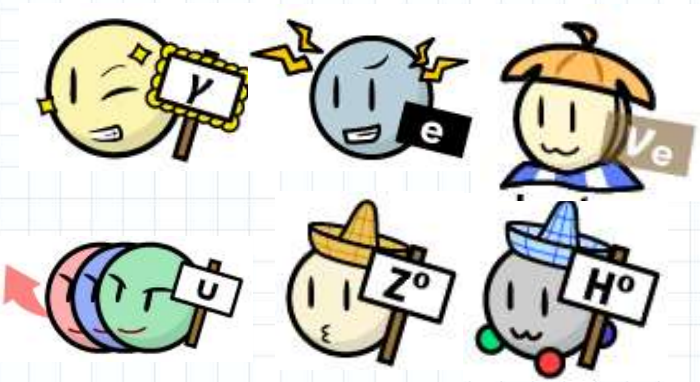
Start rad.

$T_{BH} \simeq M_{BSM}$

$T_{BH} < M_{BSM}$

PRESENTATION

BH



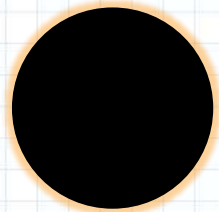
SM Particles

Graviton

$T_{BH} < M_{BSM}$

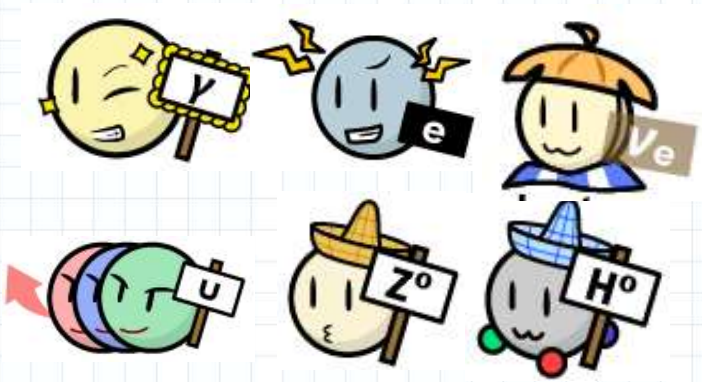
PRESENTATION

BH



Graviton get

$$\frac{g_{GW}}{g_{SM}} \times dM_{BH}$$



SM Particles

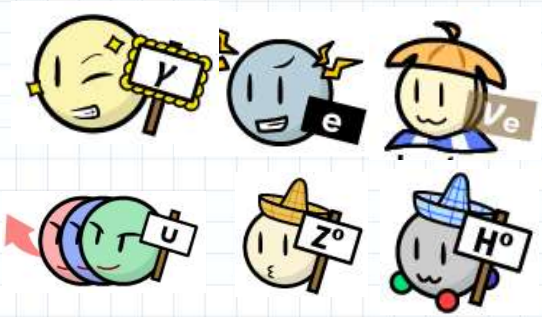
Graviton

$T_{BH} > M_{BSM}$

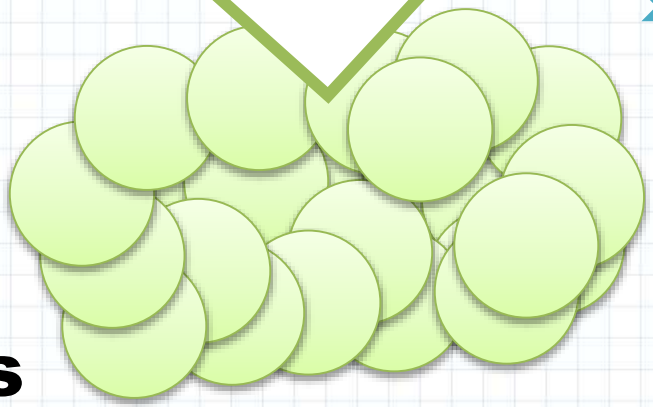
PRESENTATION

BH

$$\frac{g_{GW}}{g_{SM} + g_{BSM}} \times dM_{BH}$$



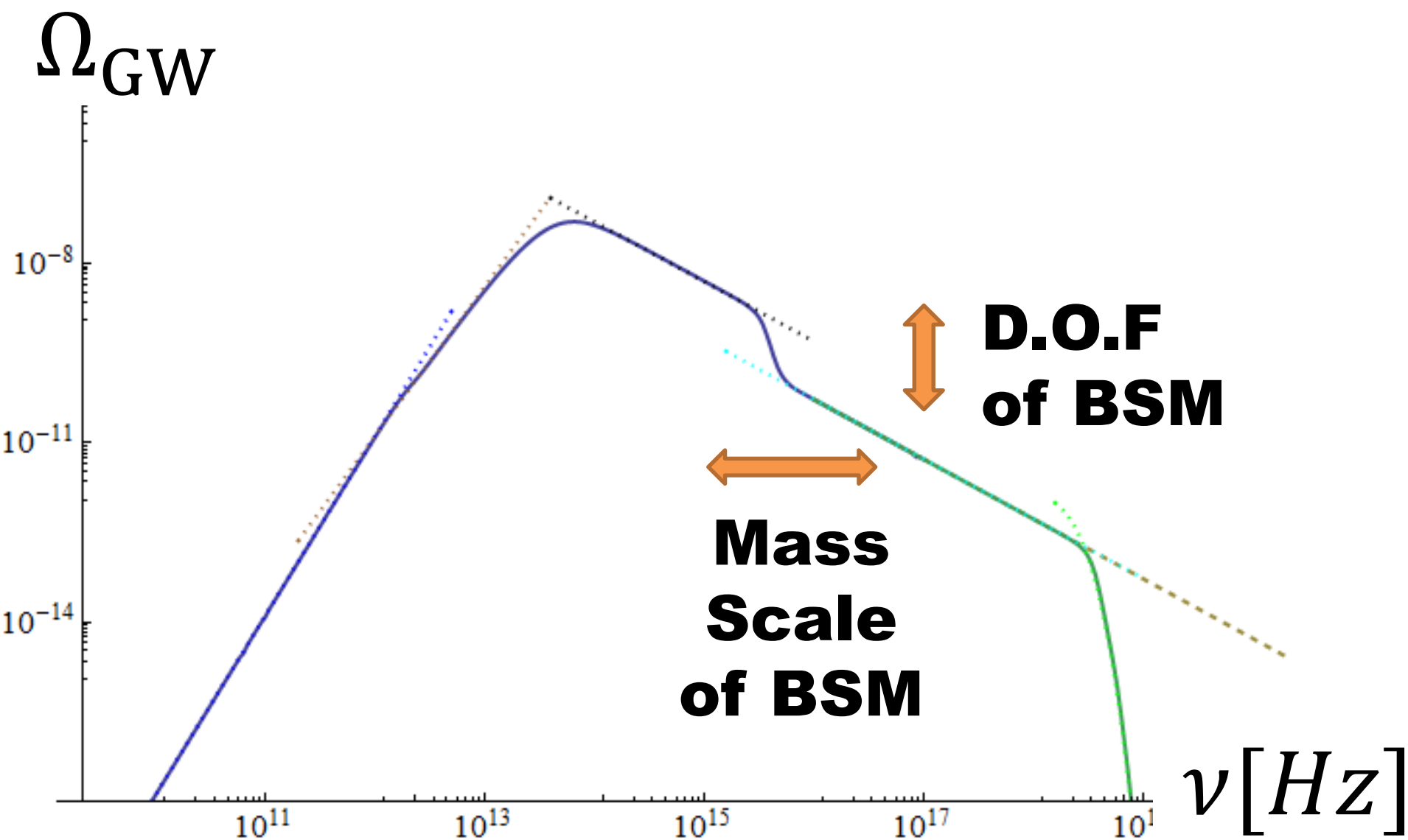
SM Particles



BSM Particles

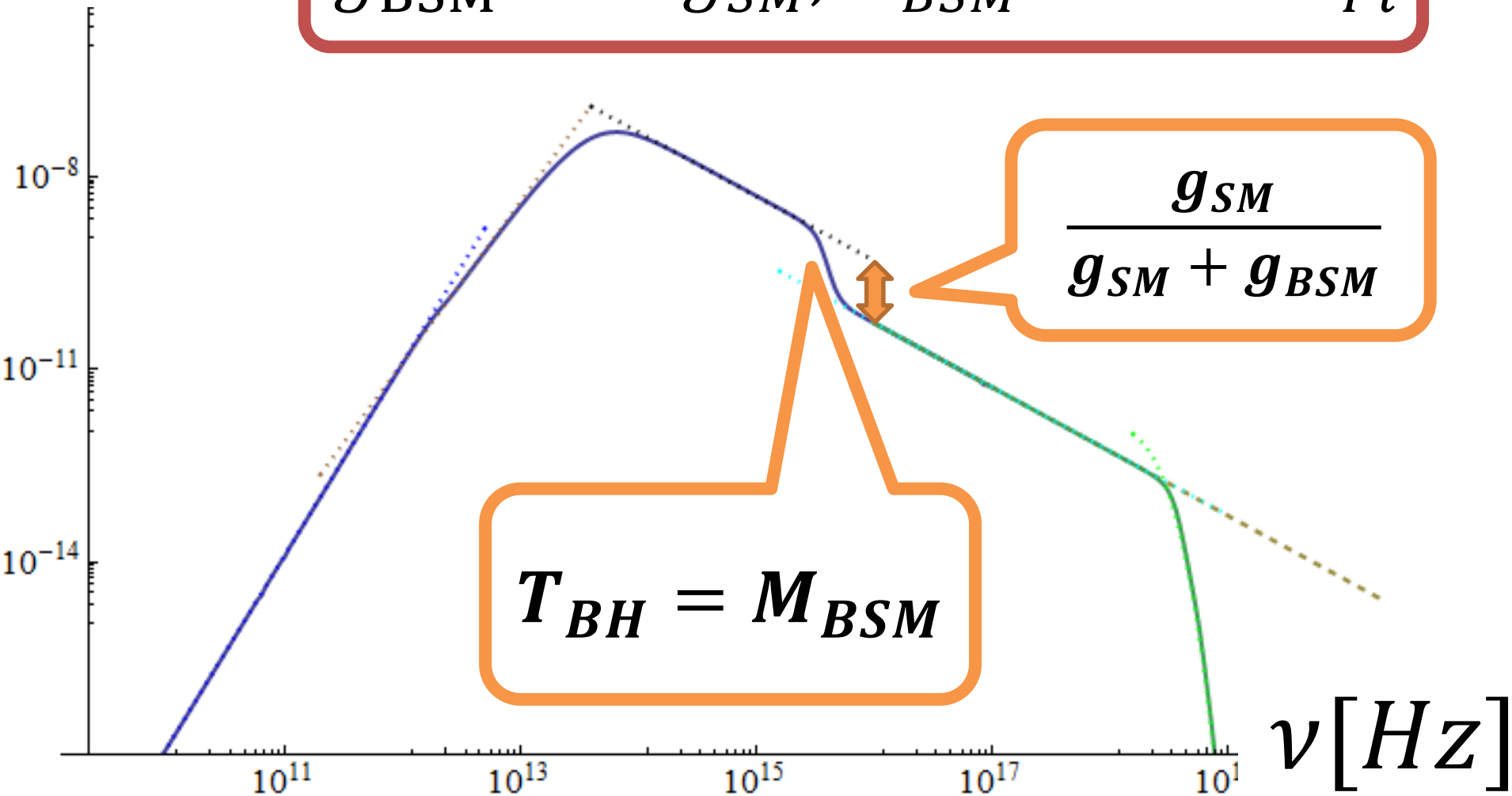
Graviton

GW spectrum from PBH



GW spectrum from PBH

$$g_{\mathrm{BSM}} = 10 g_{SM},\ E_{BSM} = 10^{-3} M_{Pl}$$



$$\frac{g_{SM}}{g_{SM} + g_{BSM}}$$

$$T_{BH} = M_{BSM}$$

Dark sector is detectable


Possible to observe ?

Setup

PRESENTATION

PBH initial mass & Temp

- $\mathrm{M}_{BH} = 10^5 M_{Pl}$
- $T_{BH} = 10^{-5} M_{Pl}$

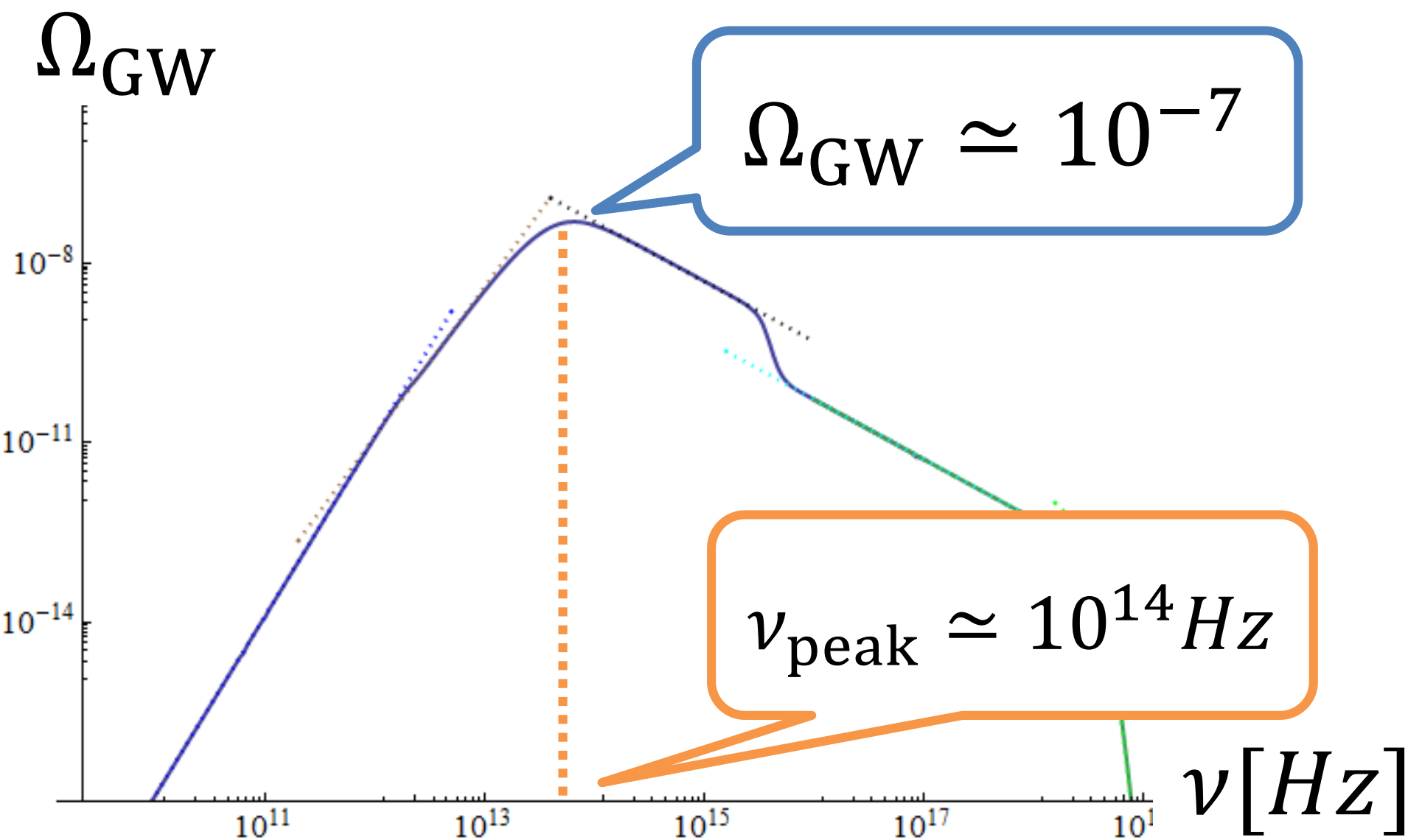
PBH forms by inflation fluctuation or preheating.

PBH initial energy fraction

- $\Omega_{BH}(t_{\mathrm{form}}) > 10^{-5}$

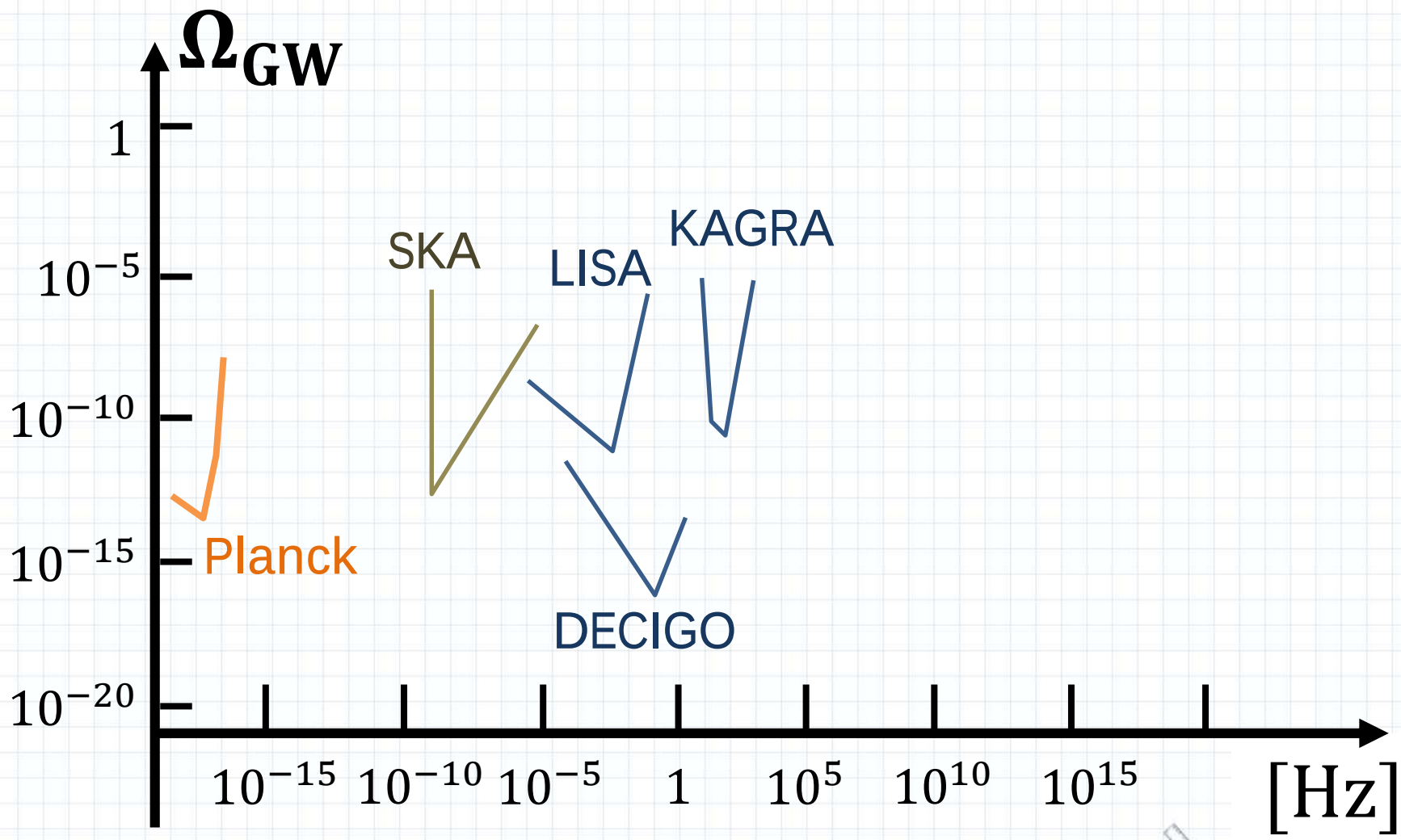
PBHs once dominate the universe.
the result does not depend on $\Omega_{BH}(t_{\mathrm{form}})$.

GW spectrum from PBH



Observability

PRESENTATION

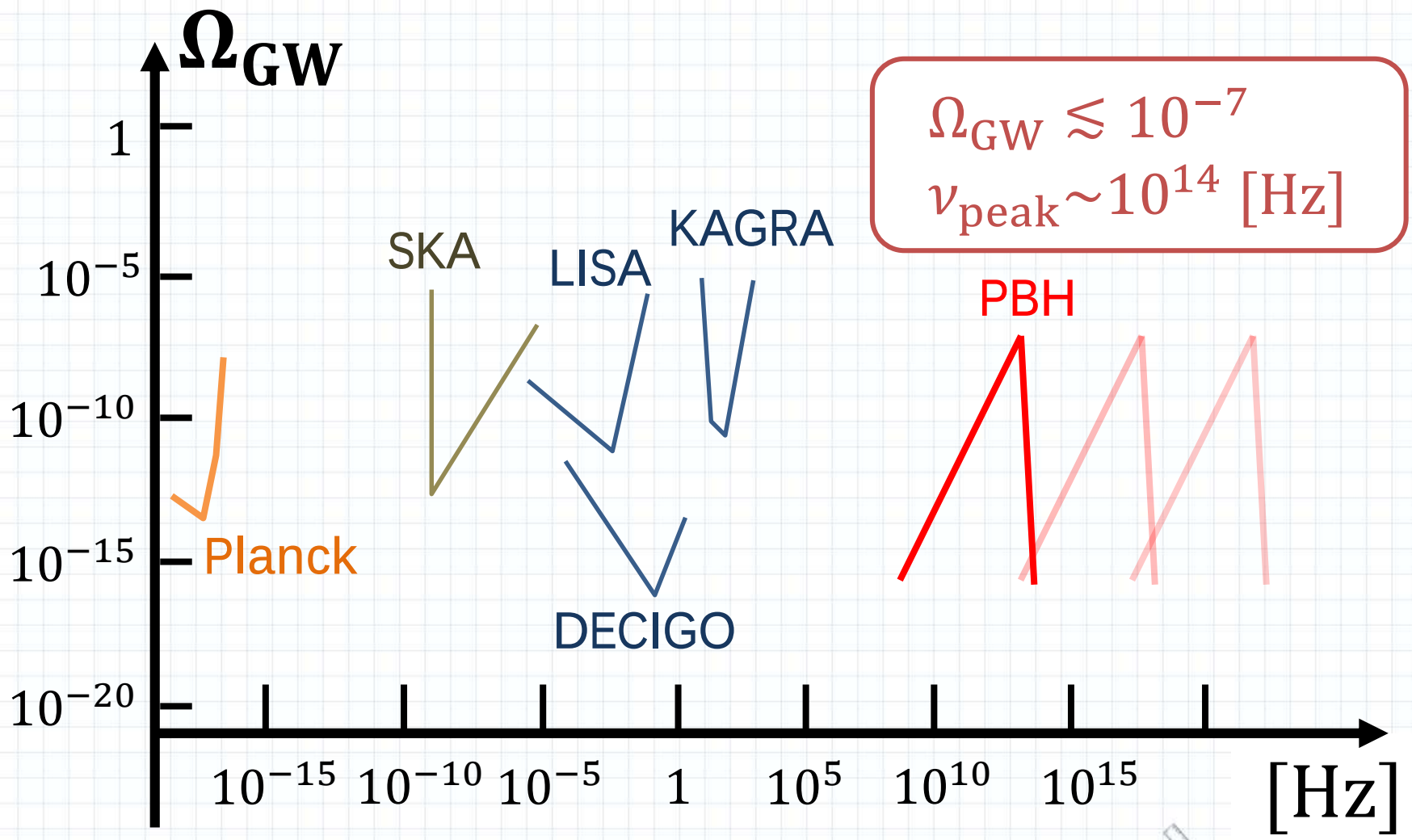


Frequency[Hz]

Observability

PRESENTATION

[Anantua+(2009); Dolgov&Ejlli(2011), T.F+(2014)]



$\Omega_{GW} \lesssim 10^{-7}$

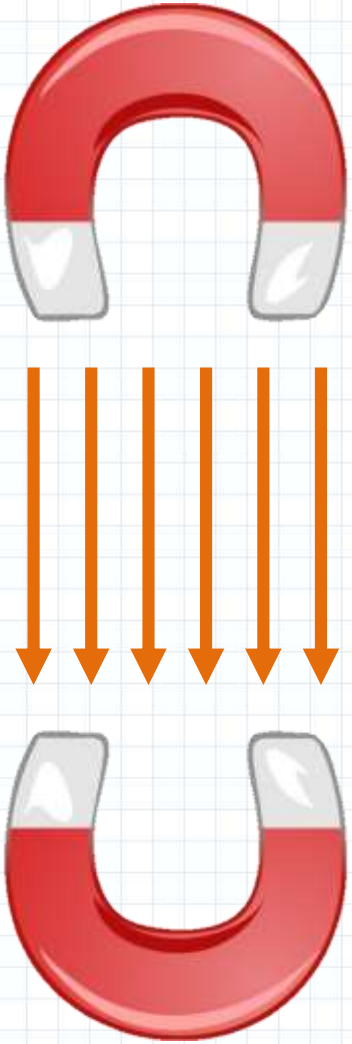
$\nu_{peak} \sim 10^{14}$ [Hz]

Frequency[Hz]

Gertsenshtein-effect

PRESENTATION

Magnetic Field



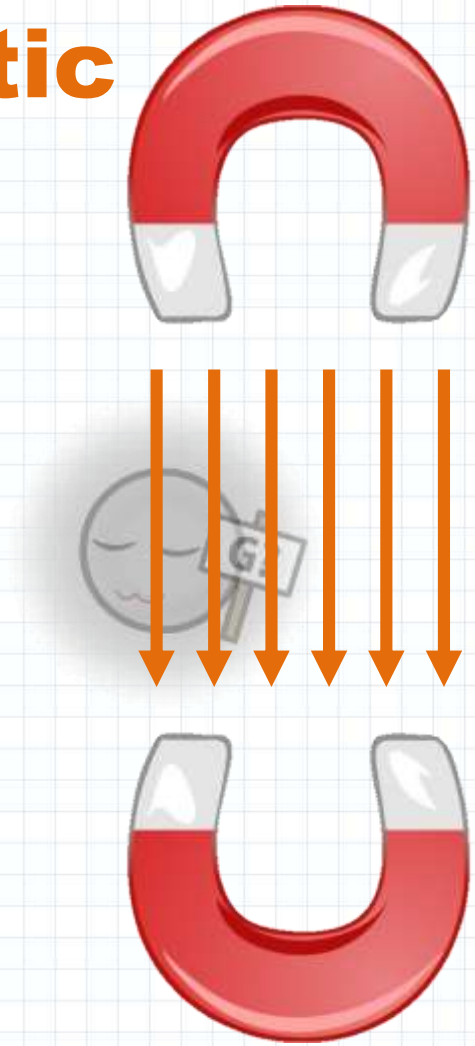
Graviton

Invisible

Gertsenshtein-effect

PRESENTATION

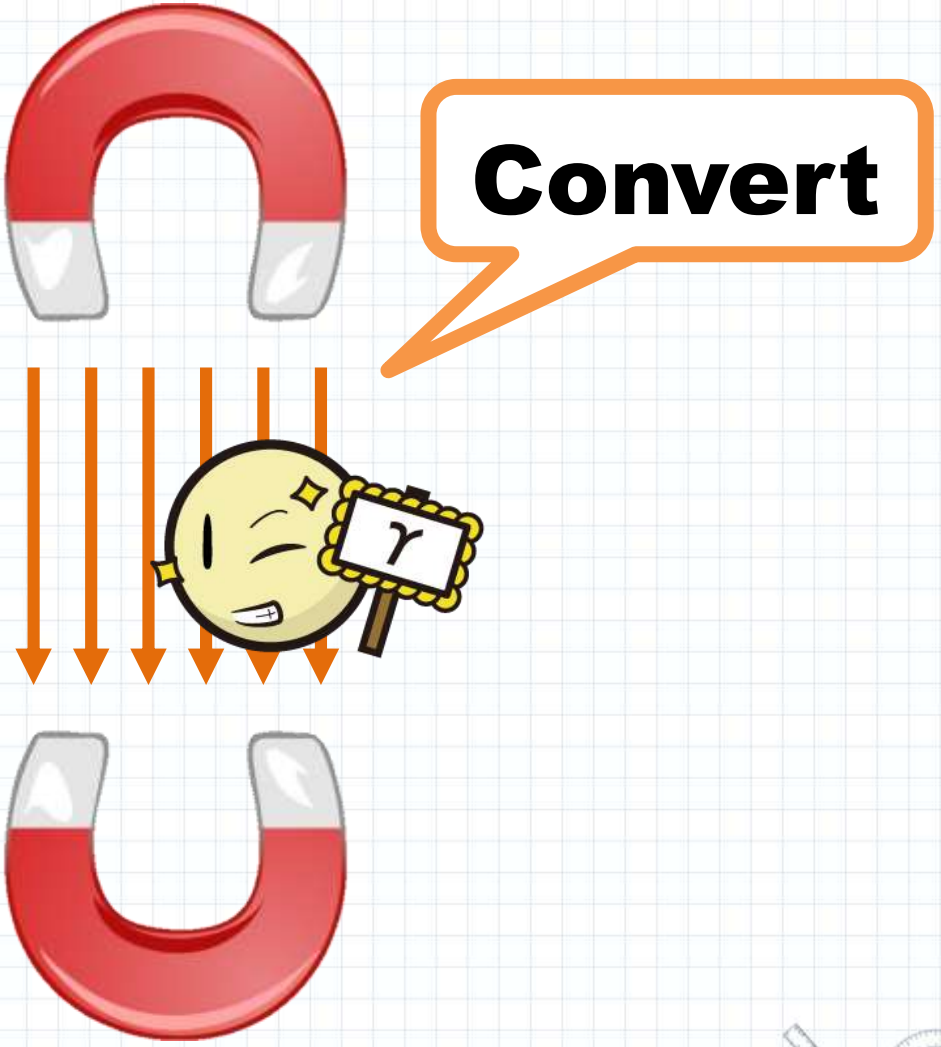
Magnetic Field



Gertsenshtein-effect

PRESENTATION

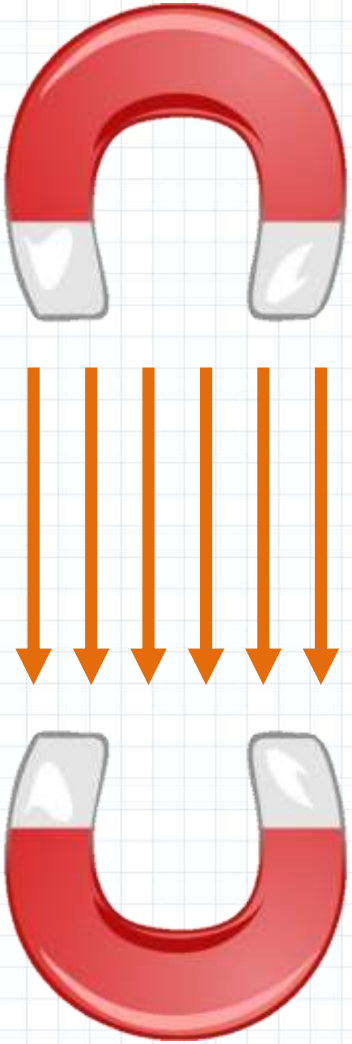
Magnetic Field



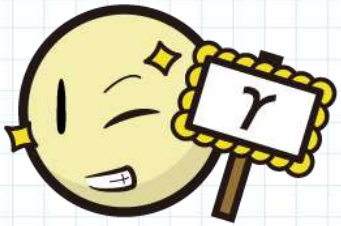
Gertsenshtein-effect

PRESENTATION

Magnetic Field



Visible



Photon

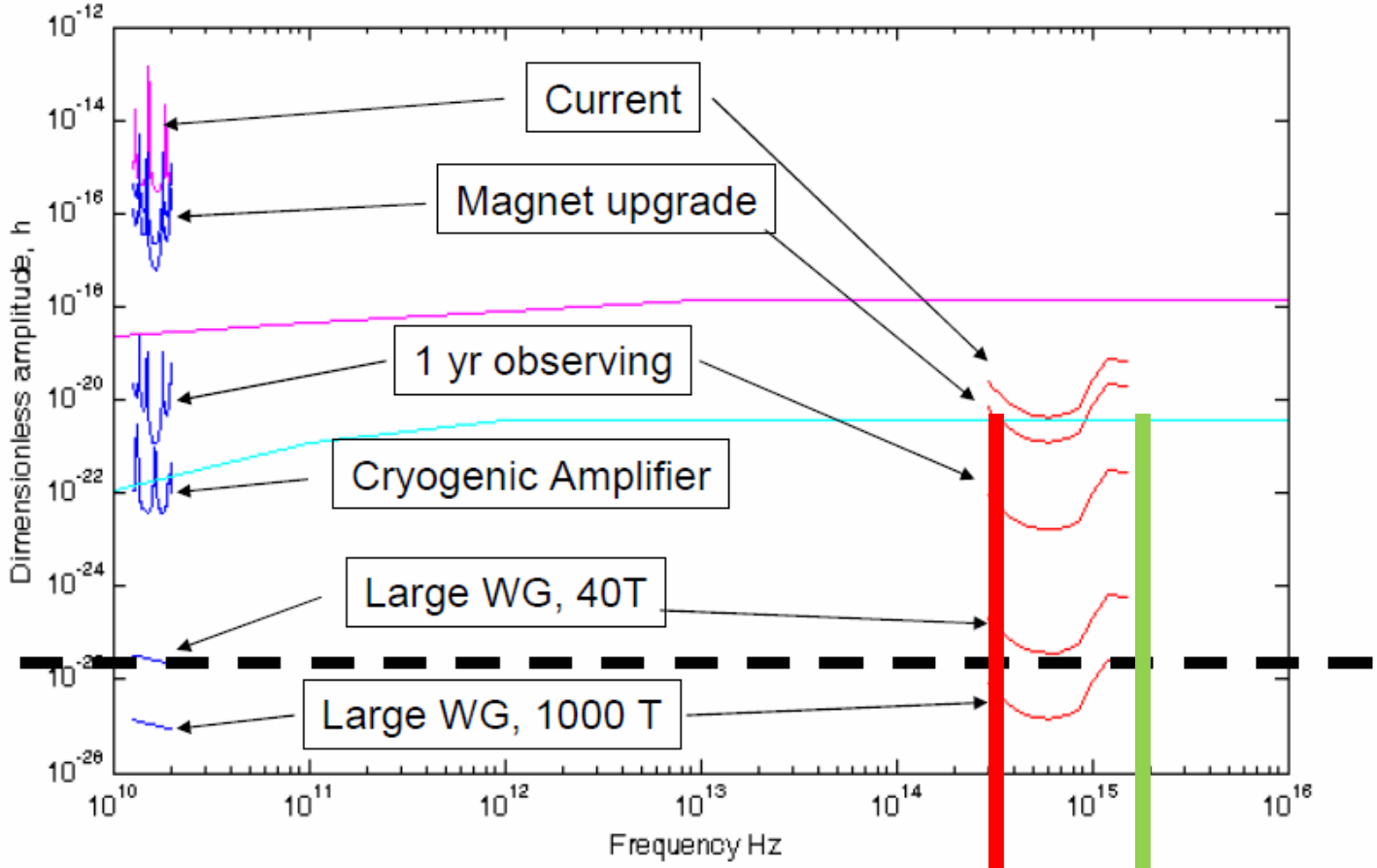
G-effect detector

PRESENTATION

[Cruise+(2006), Li+(2008), Cruise+(2012)]

- Prototype detector was made
- Experimentalists are discussing ideas improving sensitivity

Development Path- no seeding



$h_{\text{peak}} \simeq 10^{-35}$

10^{-14}

$h_{\text{GUT}} \simeq 10^{-38}$

10^{-17}

Conclusion

PRESENTATION

We can observe
the mass spectrum
of new physics
by GW from PBH

Discussion

PRESENTATION

① Existence of PBH?

② If PBH has broad mass spectrum

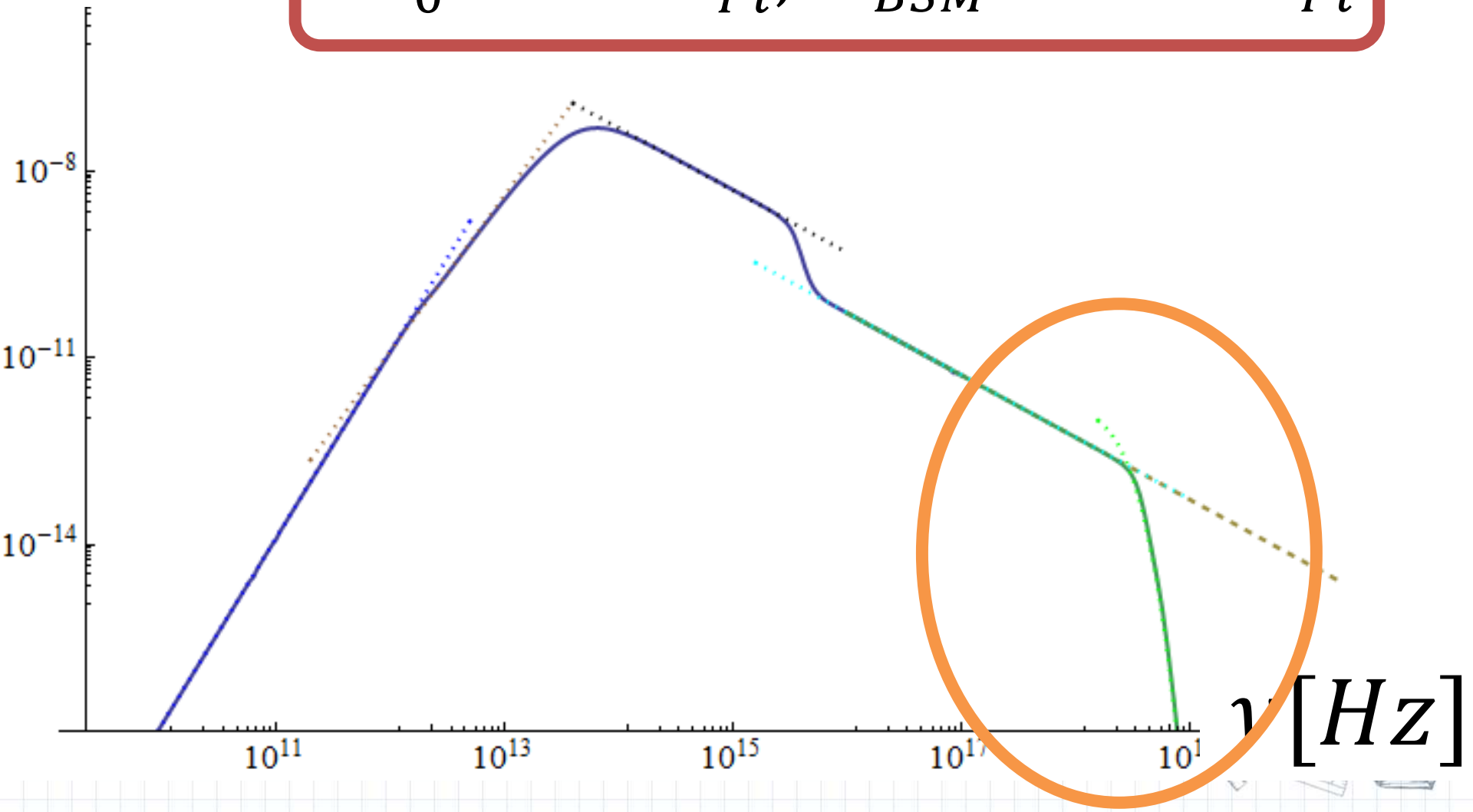
③ Only $\mathrm{E} > \mathrm{T}_0$ is detectable

④ Calculate Ω_{GW} using a model

⑤ Beyond Planck Scale ?

GW spectrum from PBH

$$\mathrm{M}_0 = 10^5 M_{Pl},\ E_{BSM} = 10^{-3} M_{Pl}$$



Conclusion

We can observe
the mass spectrum
of new physics
by GW from PBH

Thank you!

Gertenshtein-effect

[Gertenshtein(1966)]

With GW  and Static MF 

Maxwell eq. has a source term.

$$\nabla \times \boldsymbol{B} = \dot{\boldsymbol{E}} + ikB_s\, \boldsymbol{h} e^{i(kz-\omega t)}$$

induces 

Effective D.o.F

[Page(1976), MacGibbon(1991)]

$$g_{\text{boson}} = 1, \qquad g_{\text{fermi}} = 7/8$$

Effective D.o.F of Hawking rad. depends on **spin**

$$g_{s=0} = 7.26,$$
$$g_{s=1/2} = 4.00,$$
$$g_{s=1} = 1.63,$$
$$g_{s=2} = 0.18,$$

Effective D.o.F

PRESENTATION

$$\Delta g = 50.26,$$

3 Scalars
3 Spinors
10 vectors
1 Tensor