Novel Observable of BH's Mass and Spin

exponential gravitational redshift near BH horizon

and a supplemental preliminary result for Sgr A*
found after registrating for this conference $\downarrow$

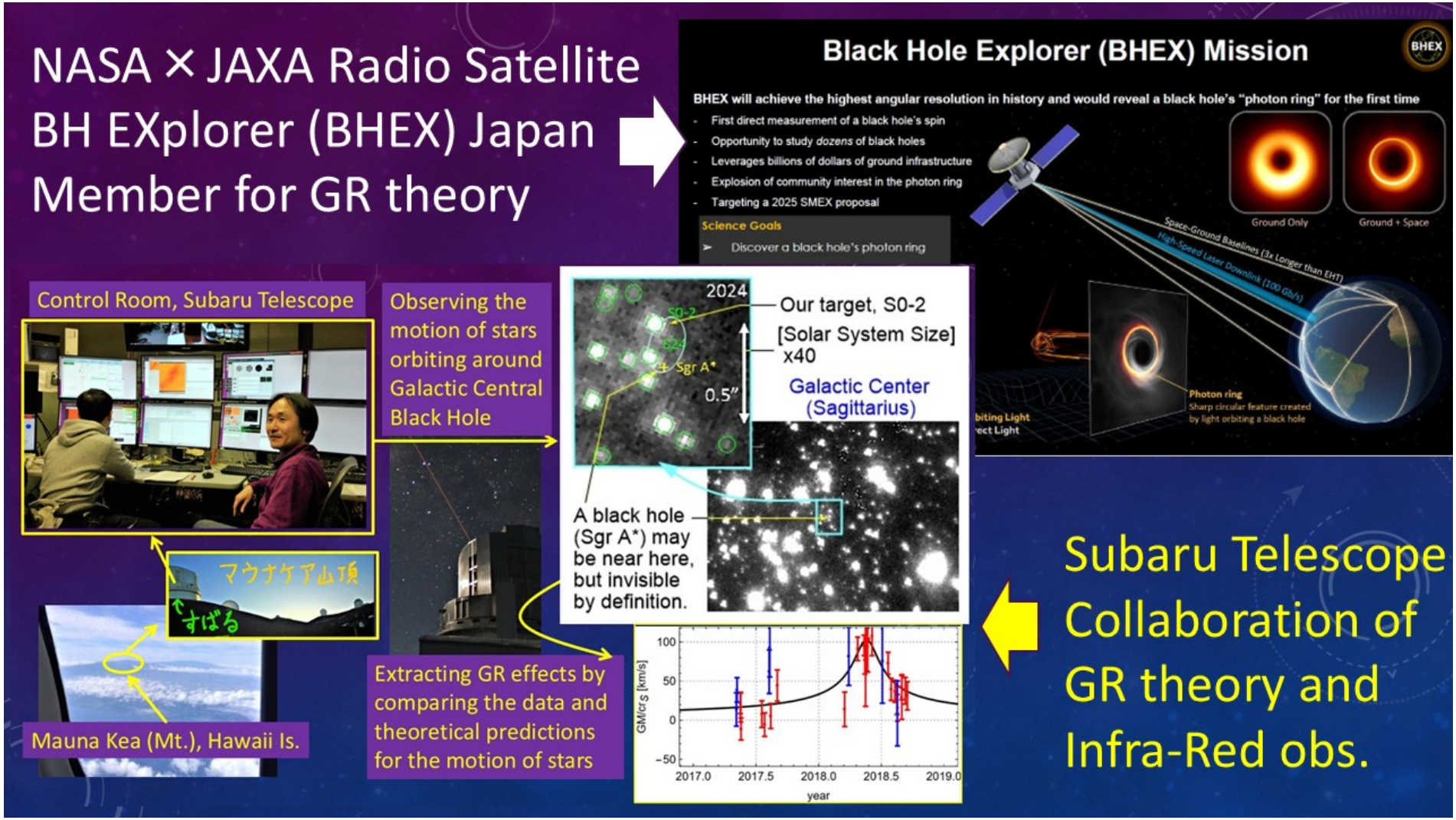
Dark Matter Accumulation around Sgr A*

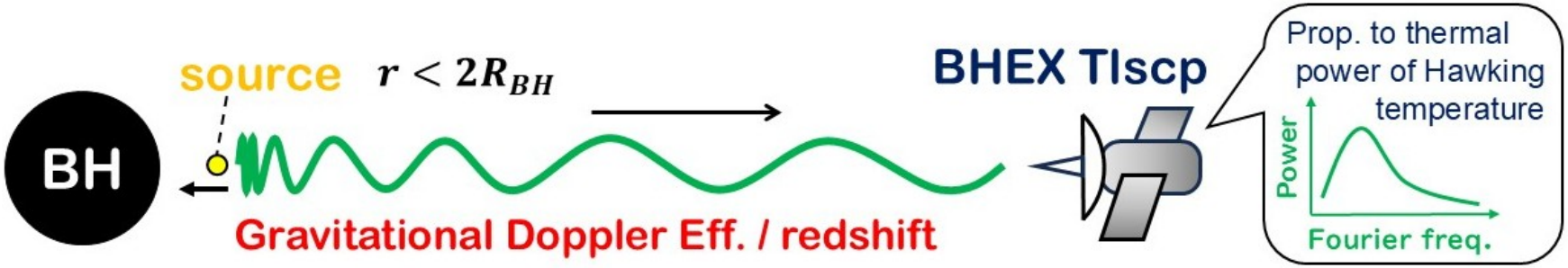
General Relativity fitting with S0-2 star

SAIDA Hiromi (Daido Univ.)

+ Collabrators in BHEX-Japan and Subaru-GC team

DAIDO UNIVERSITY



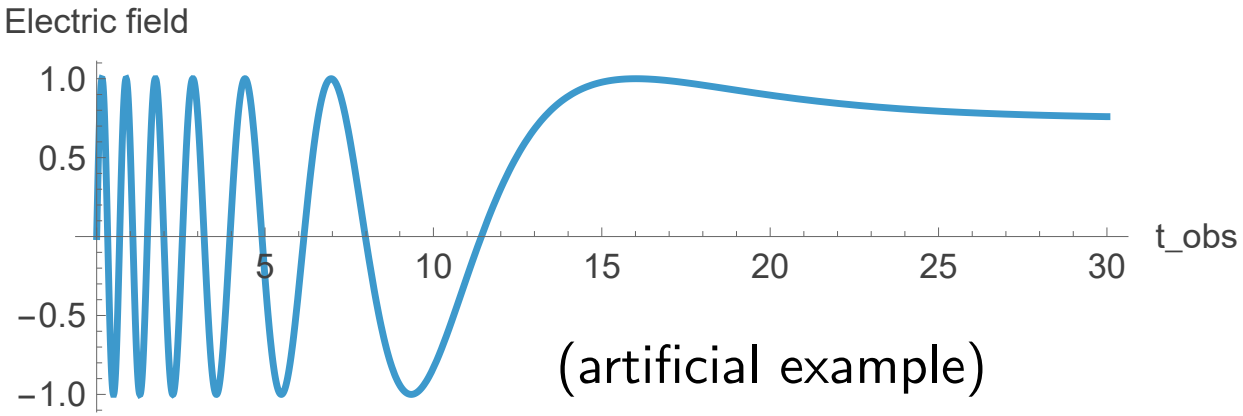


Exponential Redshift at Observer for $r_{\rm emi} < 2r_{\rm BH}$

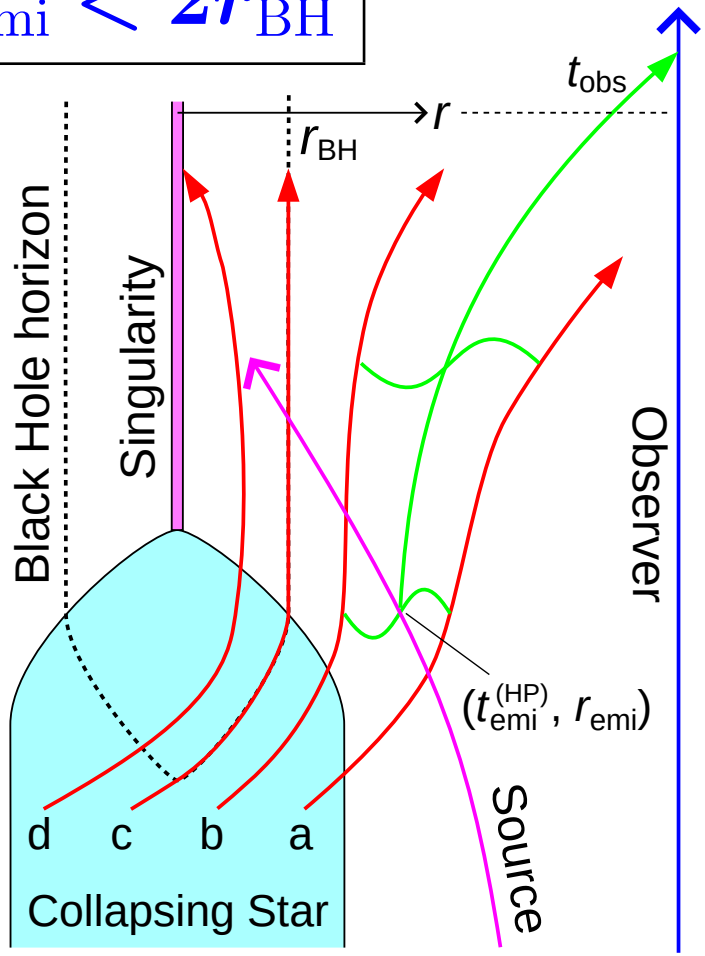
$$\Omega_{\rm obs}(t_{\rm obs}) \to \Omega_{\rm emi}\exp(-\kappa\, t_{\rm obs})$$

$$\kappa = \frac{\sqrt{1-(a/m)^2}}{2r_{\rm BH}}$$ surface grav. at BH horizon

$\Rightarrow$ Temporal Oscillation of this wave



(artificial example)



– Novel Obs. of BH's mass & spin / comments on left panels –

- A light source is falling into Black Hole. (see left figures)
- Far observer keeps receiving photons emitted by the falling source.
- BH gravity causes **Gravitational Redshift** on each photon.
- The Grav.Redshift is given by the difference of grav. potential between the emission point ($r_{\rm emi}$) and obs. point ($r \to \infty$) and independent of plasma physics.
- As the falling source approaches to BH horizon, the Grav.Redshit on observed photon get stronger.
- After the source falling into the BH's vicinity of $\boldsymbol{r_{\rm emi} < 2r_{\rm BH}}$, the observed frequency **decays exponentially** as $t_{\rm obs}$ goes !

$\to$ Left graph is **a typical observed oscillation** of EM wave.

$\Rightarrow$ **Fourier Power Spectrum of this time series data**

$$\boxed{\left|f_{\rm obs}(\omega)\right|^2 = \frac{A_{\rm obs}^2}{\omega}\frac{1+O(\varepsilon)}{\exp\left[2\pi\,\omega/(c\kappa)\right]-1}} \quad \text{for } r_{\rm emi} < 2r_{\rm BH}$$

$$\varepsilon := r_{\rm emi}/r_{\rm BH} - 1 \ \ (<1)$$

$\propto$ Thermal spectrum of Hawking temperature $T_{\rm H}$

$$T_{\rm H} = \frac{\hbar c}{k_{\rm B}}\frac{\kappa}{2\pi} = \frac{\hbar c}{k_{\rm B}}\frac{\sqrt{1-(a/m)^2}}{4\pi r_{\rm BH}}$$

$\rightarrow$ **Measuring m and a indep. of Plasma effects**

Note: A fluid analog system has already been simulated

(H.Furuhashi, Y.Nambu & H.Saida, 2006, Class.Quant.Grav.23, pp.5417)

(gr-qc/0601066)

$\rightarrow$ A hint for detecting κ or $|f_{\rm obs}(\omega)|^2$ in BHEX?

- The decay rate $\boldsymbol{\kappa}$ of Grav.Redshift is independent of plasma, and given by only the BH's mass $\boldsymbol{m}$ and spin $\boldsymbol{a}$!
- Further, the Fourier Power of the observed oscillation is proportional to Thermal spectrum of Hawking temparature, which is given by κ indep. of plasma.
- By measuring the Grav.Redshift's decay rate κ through $\Omega_{\rm obs}(t_{\rm obs})$ or $|f_{\rm obs}(\omega)|^2$, BH's mass $\boldsymbol{m}$ and spin $\boldsymbol{a}$ can be determined well, independent of plasma physics !

Novel Observable of BH's mass and spin

Aftter the light source falls into $r < r_{\rm BH}$, Measureing the observed EM wave oscillation of exponentially decaying frequency $\Omega_{\rm obs}(t_{\rm obs})$ or its Fourier power spectrum $|f_{\rm obs}(\omega)|^2$, gives us κ to determine BH's mass m and spin a.

– DM Accumulation around Sgr A*/ comments on right panel –

- InfraRed obs. of S0-2 star orbiting around Sgr A*(16yr period)
- GR model including parameters A and B

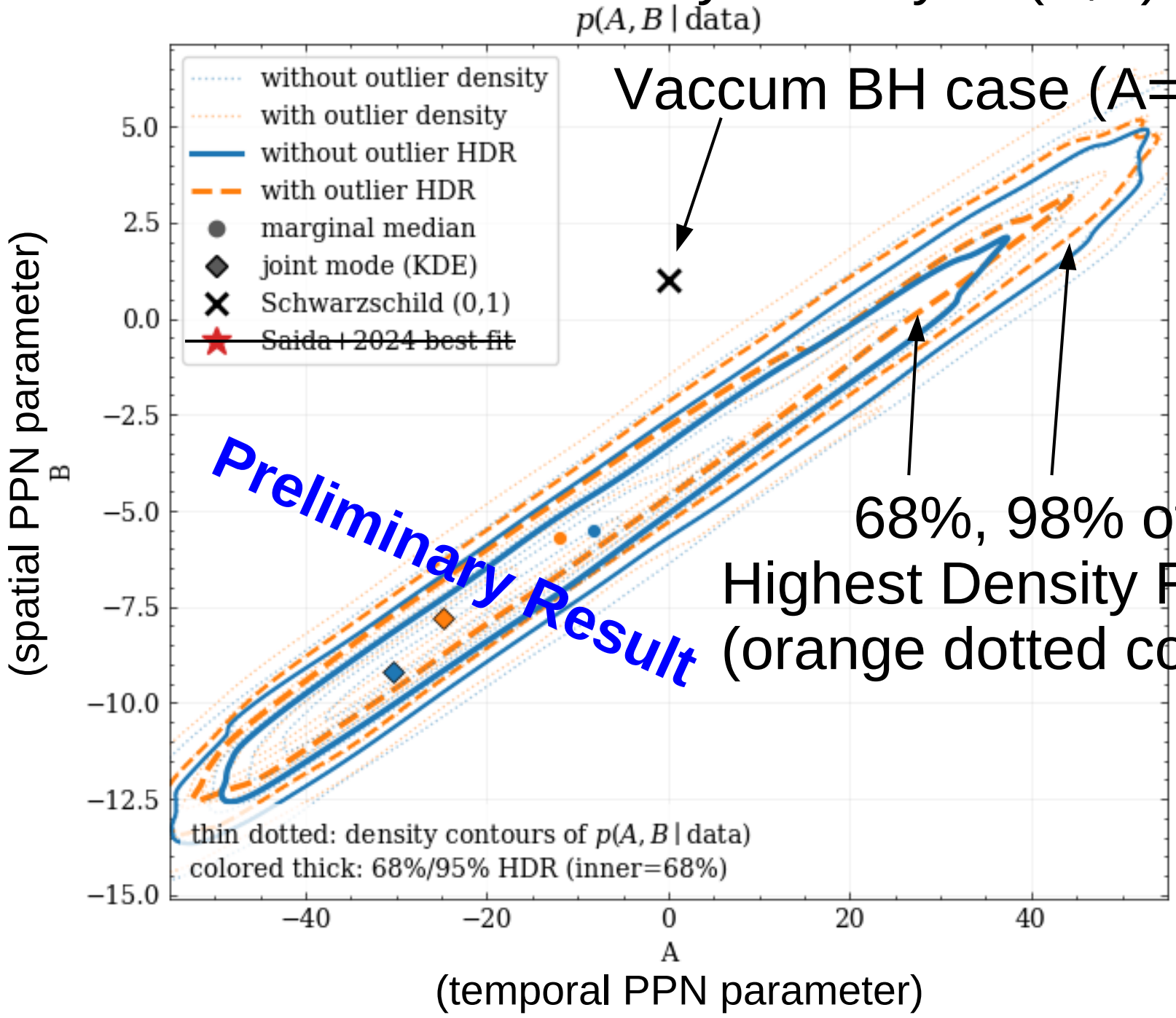
$$\begin{cases} A : \text{Deviation from vacuum BH environment in time} \\ B : \text{Deviation from vacuum BH environment in space} \end{cases}$$

  $\rightarrow$ So-called "Parametrized-Post-Newtonian (PPN)" model

  $\rightarrow$ If BH has vacuum environment, $(A, B) = (0, 1)$
- Fitting this PPN model with obs. data of S0-2's motion, the Posterior Prob. Density of (A, B) is obtained recently.
- Preliminary result is $(A, B) \neq (0, 1)$ with 98% credibility

  $\rightarrow$ **Dark Matter Accumulation around Sgr A* !?**
- Amount of DM around Sgr A*is under estimation, using an exact GR model of "BH+DM" system.

Posterior Probability Density of (A,B)



Vaccum BH case (A=0, B=1)

Preliminary Result

68%, 98% of
Highest Density Region
(orange dotted contour)

(temporal PPN parameter)