Investigation of Tidal Disruption Events Through Gravitational Waves

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LIDA workshop

Collaborators: Prof. Rossi E.M. (UniLei) , Dr. Cusin G. (IAP), Dr. Tamanini N. (L2IT), Prof. Lodato G. (UniMi)

Tidal Disruption Events (TDEs) : star torn apart by BH tides

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accretion

see reviews: vanVelzen et al 2020,
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later stages

Stein et al. 2021, Hayasaki 2021, Reusch et al. 2021

astrophysical neutrinos

couple of candidates

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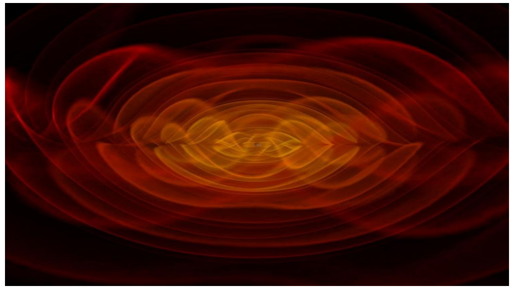
disruption



Guillochon & Ramirez-Ruiz 2009, Stone et al. 2013, Kobayashi et al. 2004, **Toscani** et al. 2019, **Toscani** et al. 2021

gravitational wave (GW) emission

Monochromatic burst

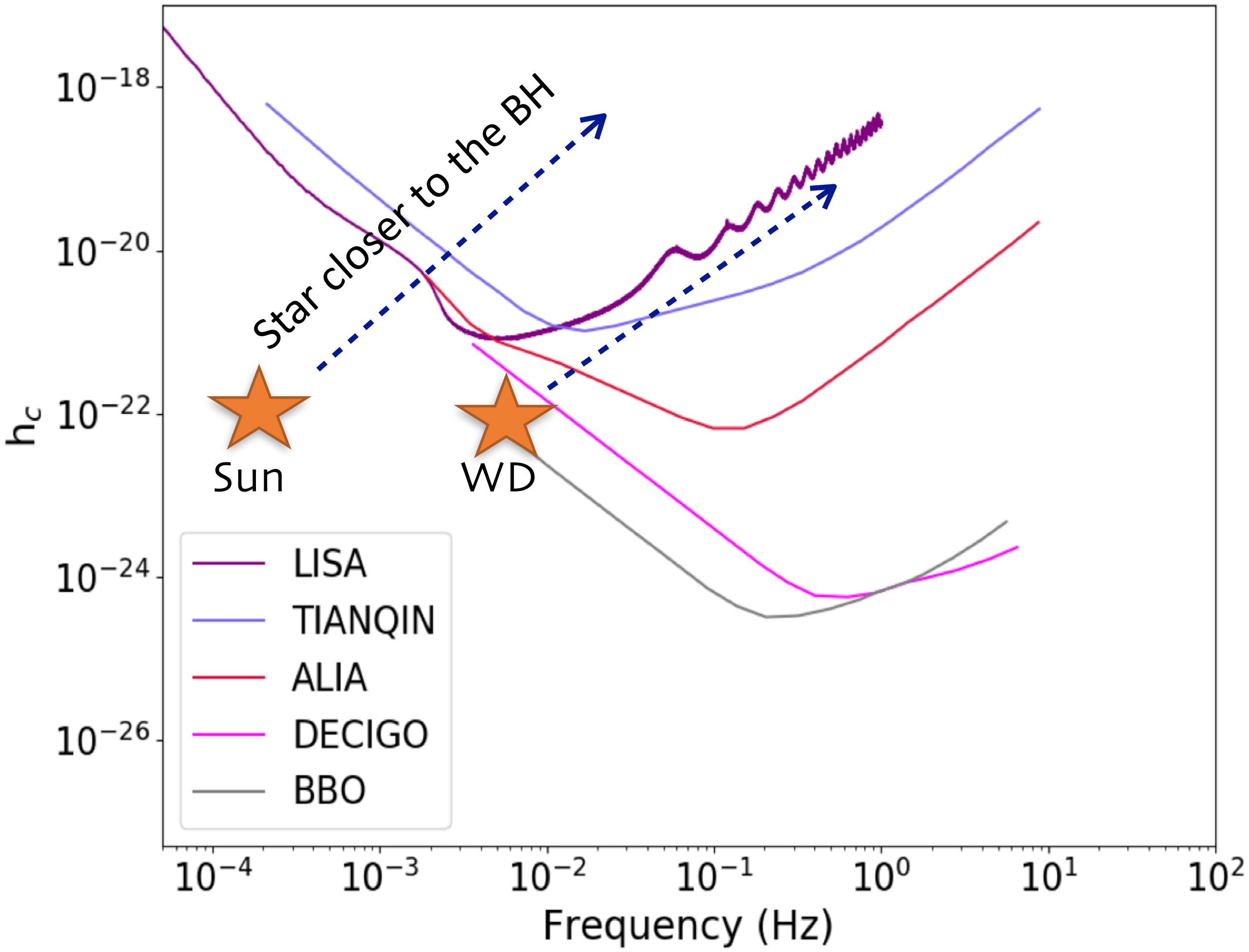
distance 20 Mpc

Sun-like star disrupted by a BH $M_h = 10^6 M_\odot$

$$h \approx 10^{-22}, \quad f \approx 10^{-4}\text{Hz}$$

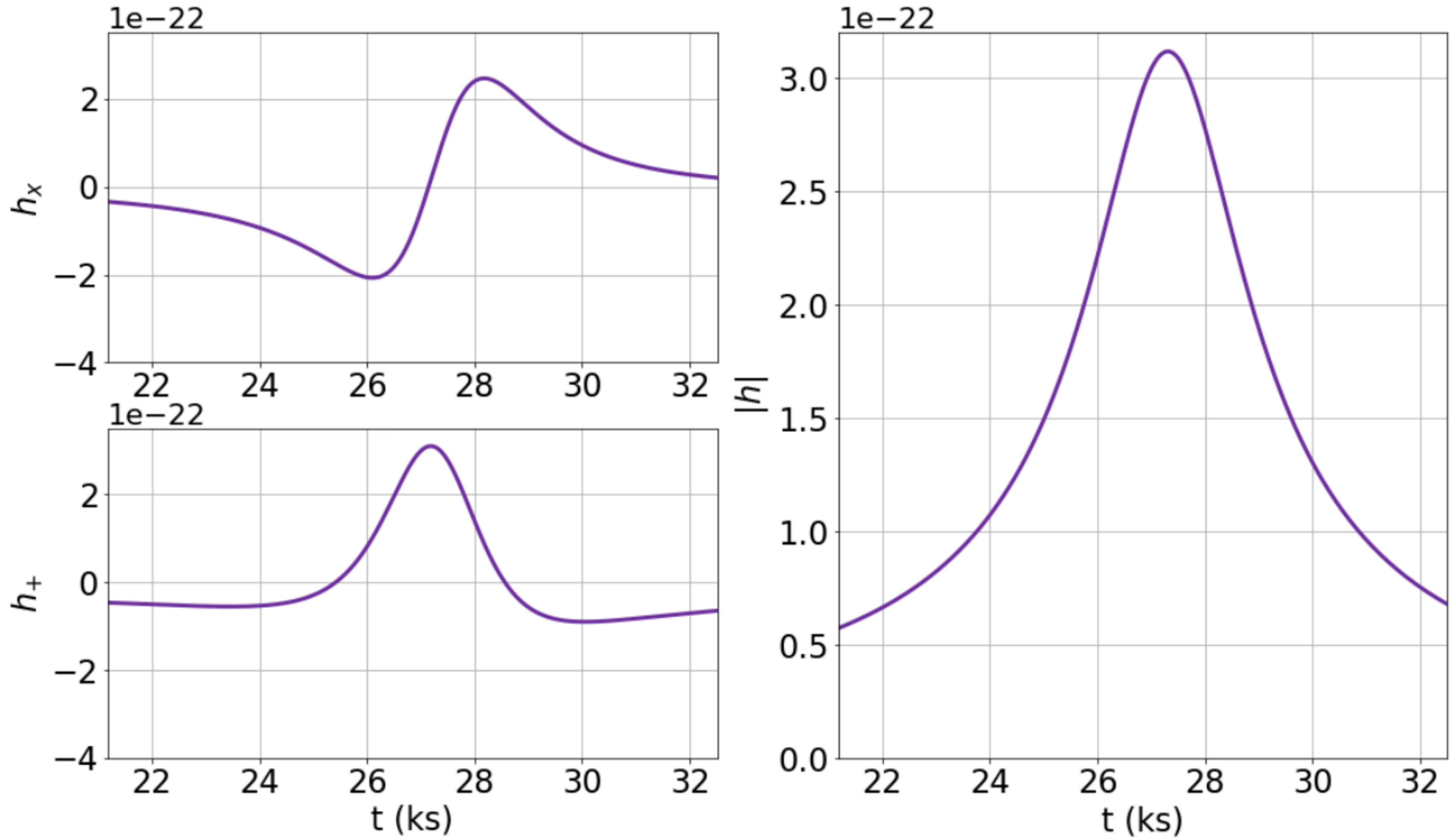
White dwarf (WD) with $M_* = 0.5 M_\odot, R_* = 0.01 R_\odot$ disrupted by a BH $M_h = 10^4 M_\odot$

$$h \approx 10^{-22}, \quad f \approx 10^{-2}\text{Hz}$$



Standard TDE at 20 Mpc

Toscani M. et al. 2021



Kerr metric

Face-on signals

$$h \approx 10^{-22}$$

$$\tau \approx 10^4 \mathrm{ks}$$

cf. Kobayashi et al. 2004

SPH code

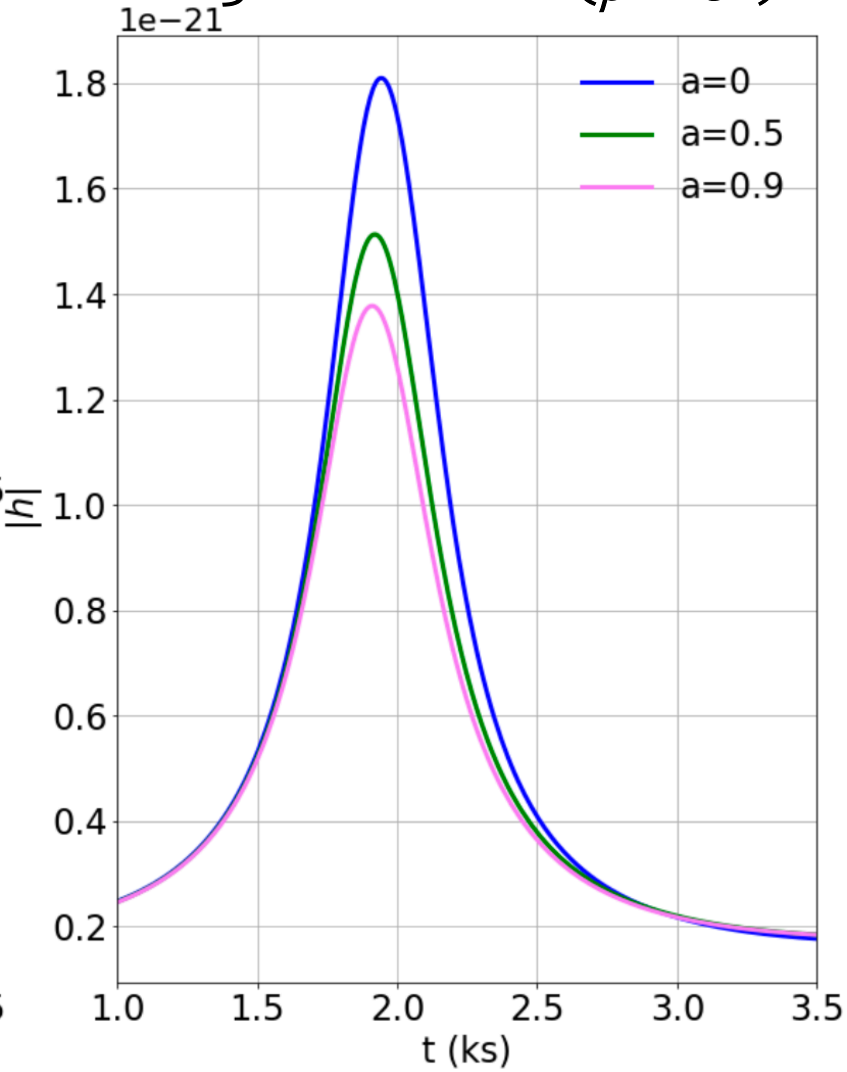
Liptai & Price 2019

https://gwcataloguetdes.fisica.unimi.it

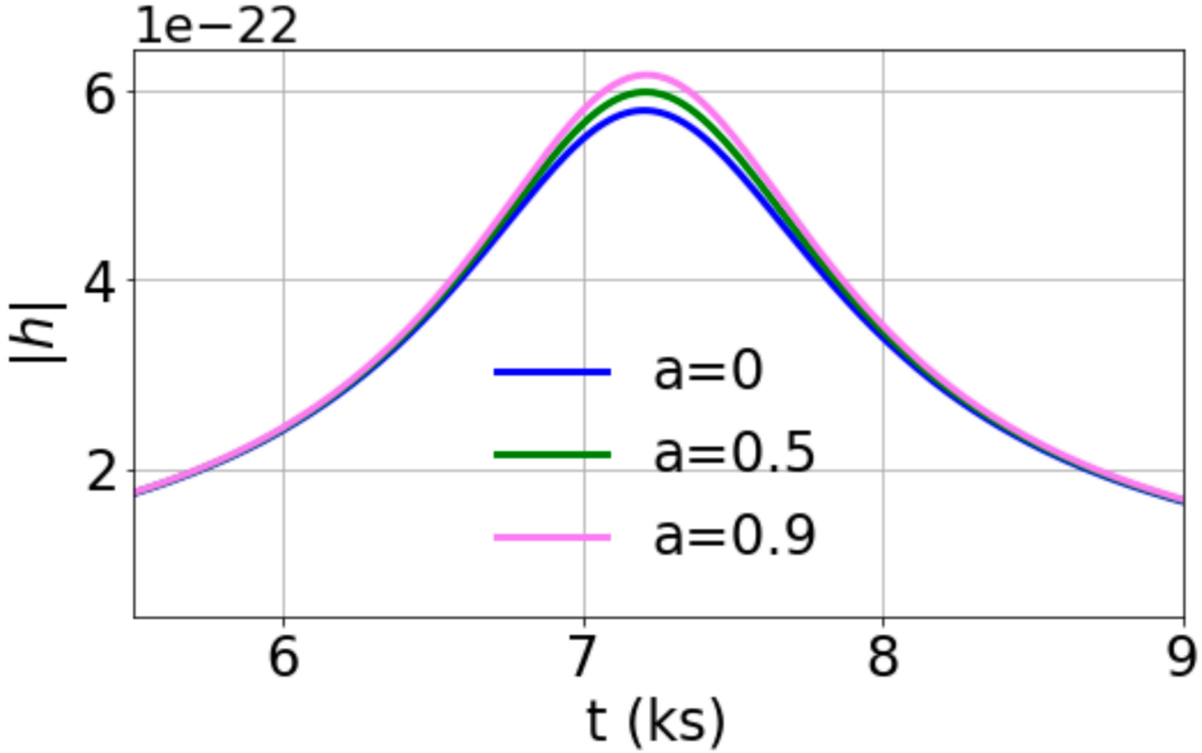
eccentricity 0.6, orbital inclination angle 0

Toscani M. et al. 2021

Prograde orbits ($\beta = 5$)



Retrograde orbits ($\beta = 2$)



GW signal increases for high retrograde orbits, decreases for high prograde orbits

Pfister, **Toscani** et al. 2022: individual detection for TDEs unlikely for LISA, promising for DECICO

GW signal from the entire cosmic population of TDEs

↓

GW background from TDES

↙ ↘

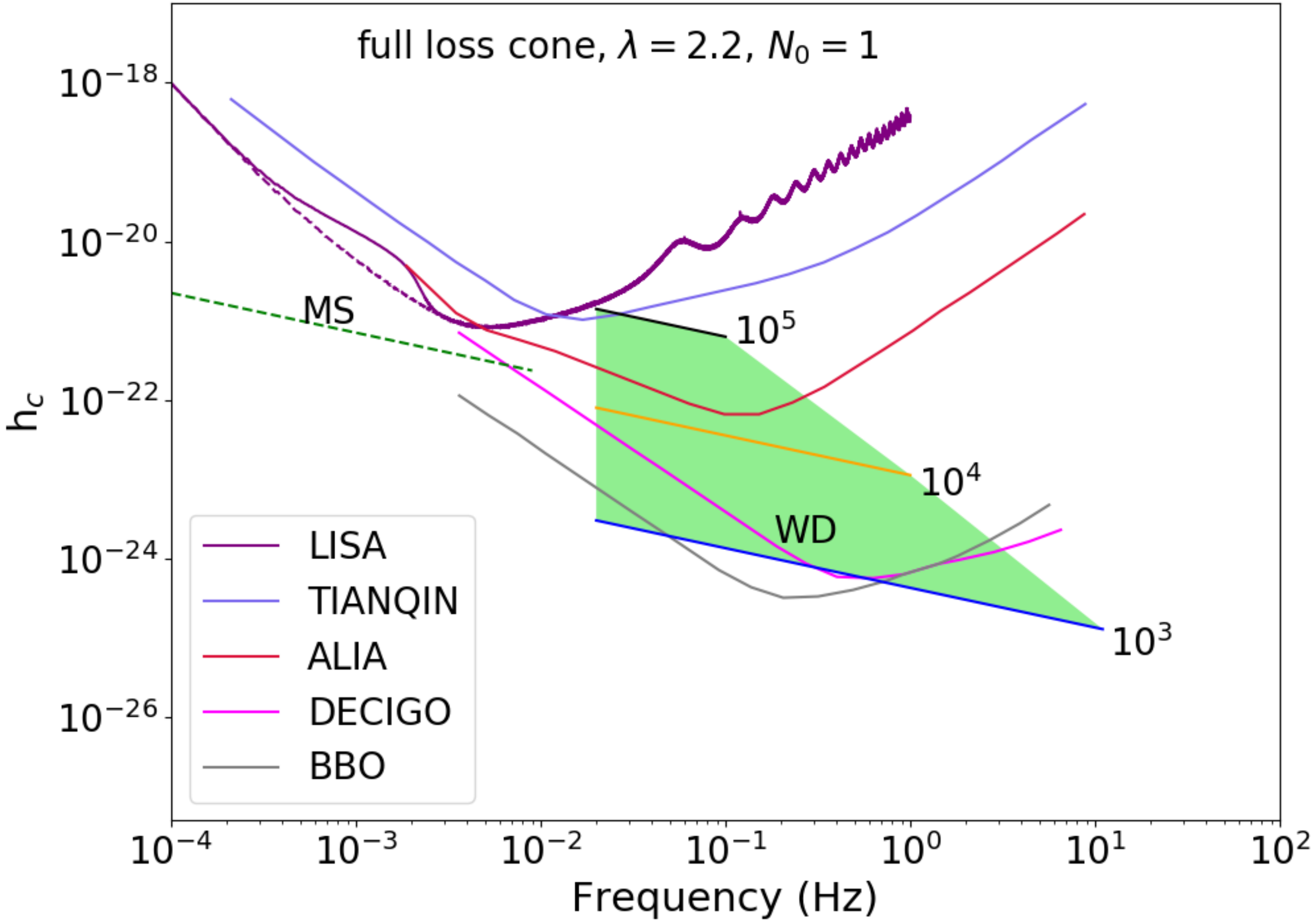
nuclear TDEs | globular TDEs

Main sequence (MS) stars disrupted by SMBHs

Vs

White dwarfs (WDs) stars disrupted by IMBHs

Toscani M. et al. 2020



$$h_c \propto f^{-1/2}$$

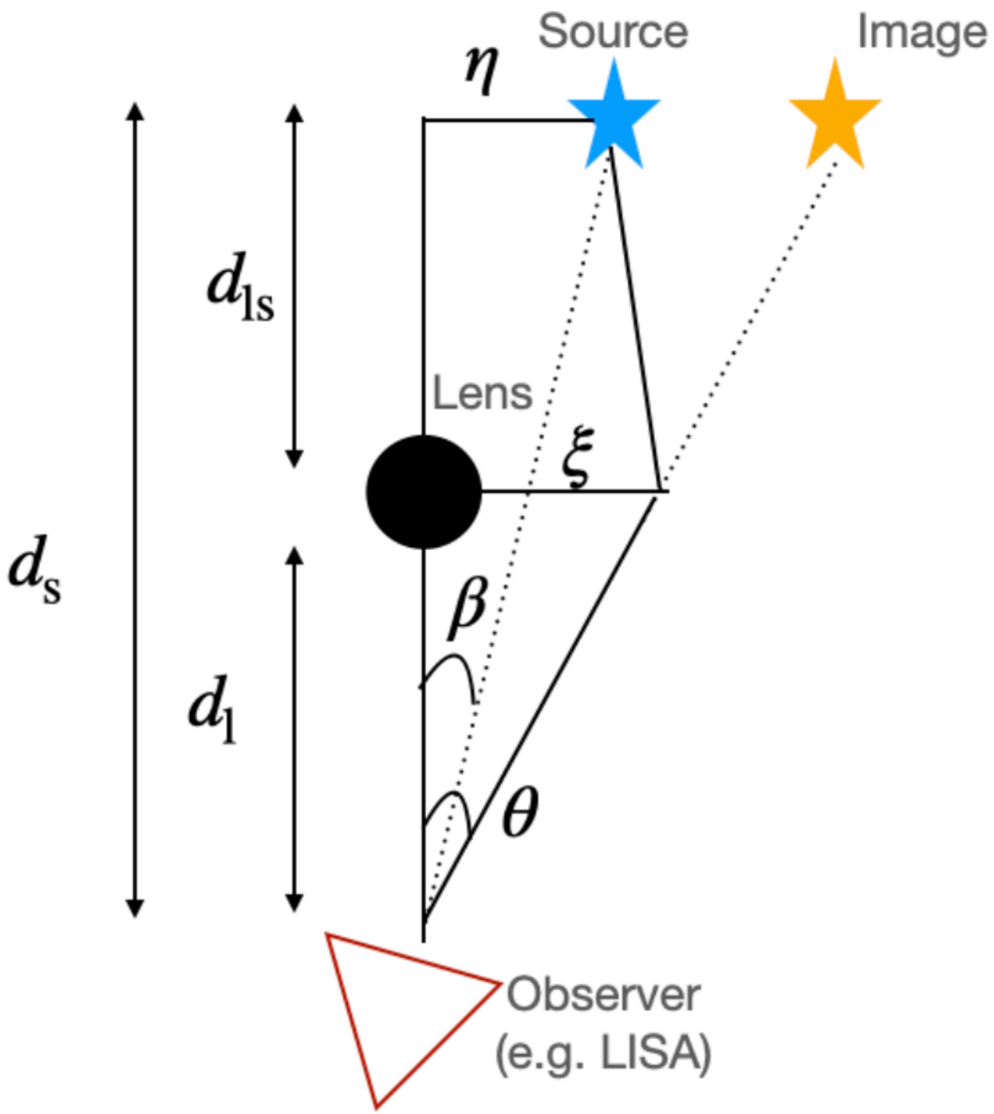
TDEs of WDs promising to map IMBHs up to redshift 3

↓

Deci-Hertz observatories

Toscani M. et al. in progress

strong lensing



multiple images

magnification of the signal

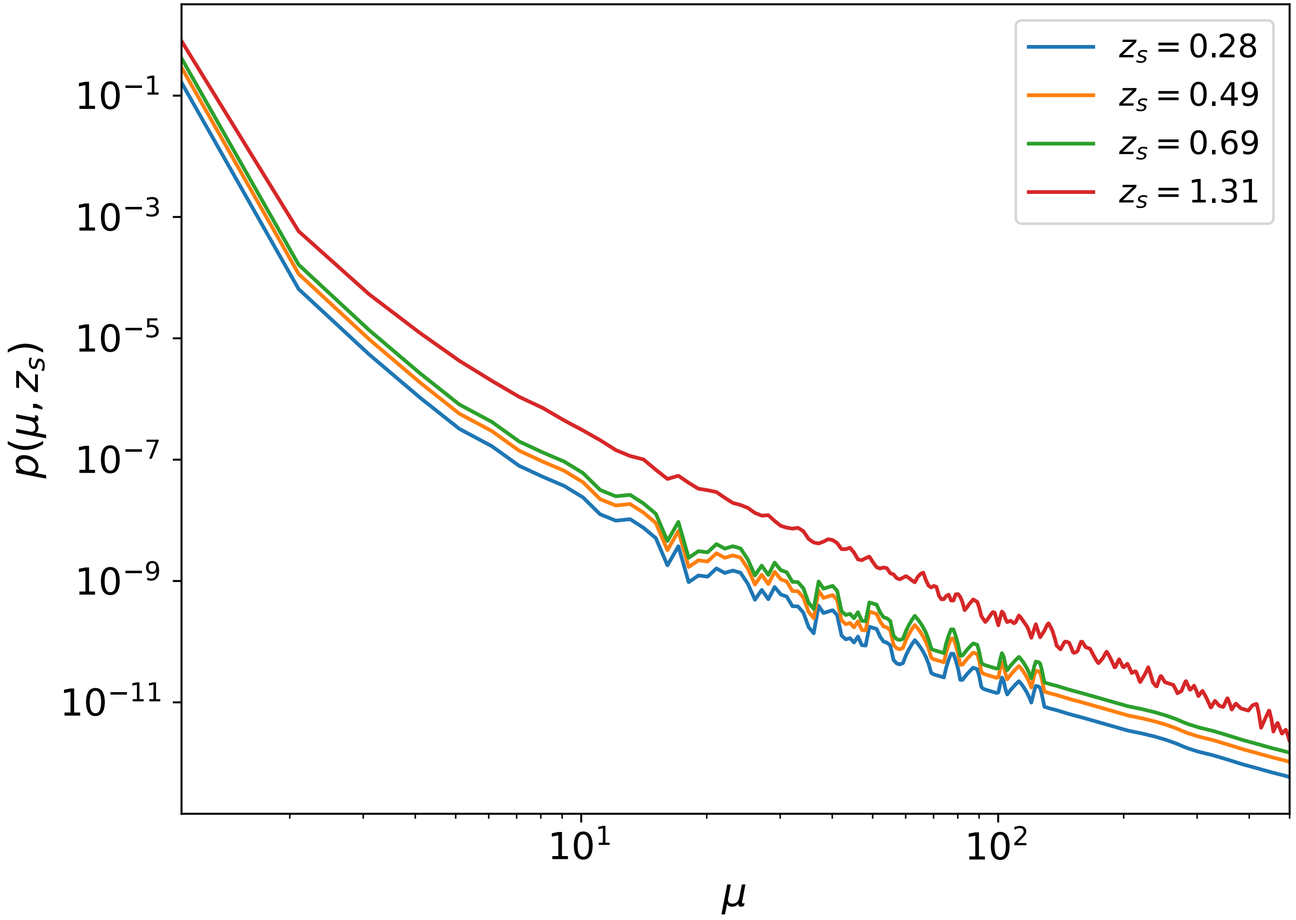
Toscani M. et al. in progress

$$\frac{d\mathcal{N}^{\mathrm{obs}}}{dz_{\mathrm{s}}} = p(\mu, z_{\mathrm{s}})\frac{d\mathcal{N}(\mu)}{dz_{\mathrm{s}}}$$

Toscani M. et al. in progress

$$\frac{d\mathcal{N}^{\rm obs}}{dz_s} = p(\mu, z_s)\frac{d\mathcal{N}(\mu)}{dz_s}$$

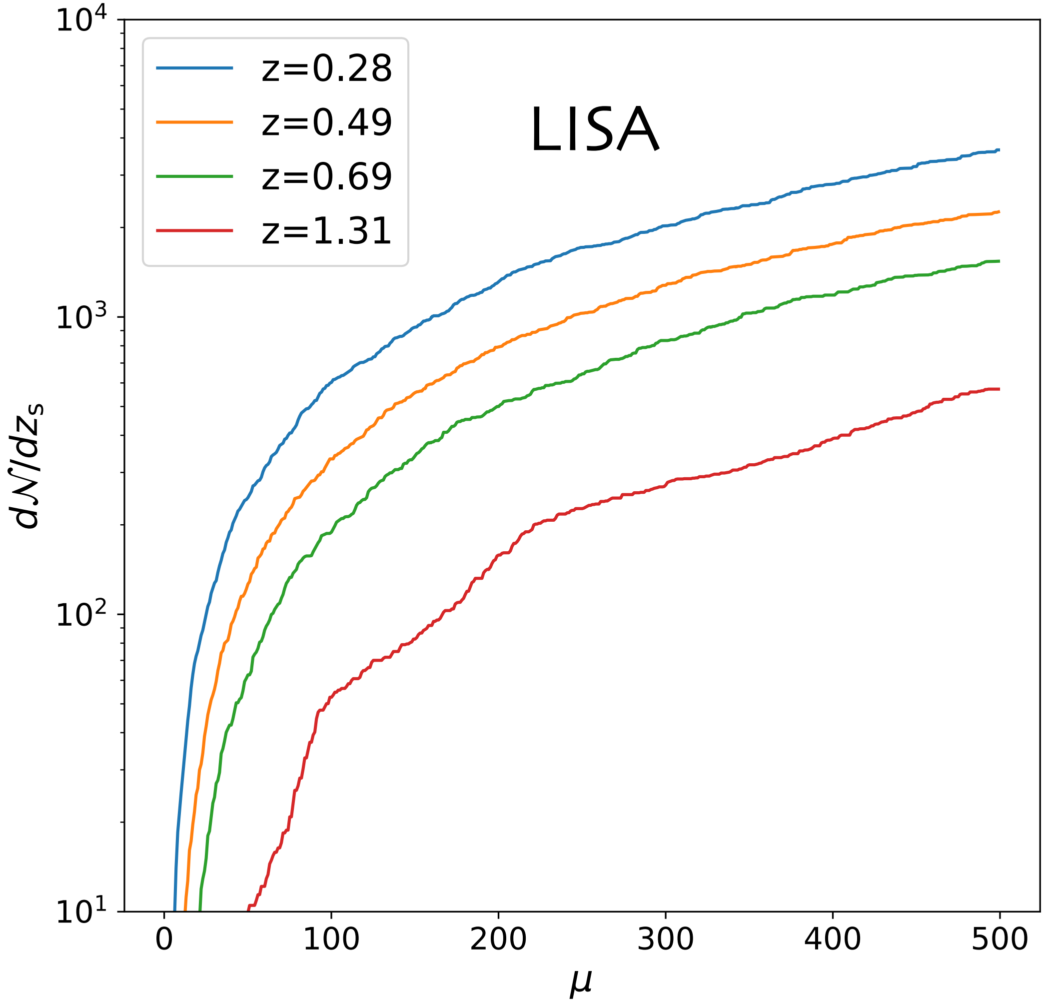
lensing probability density

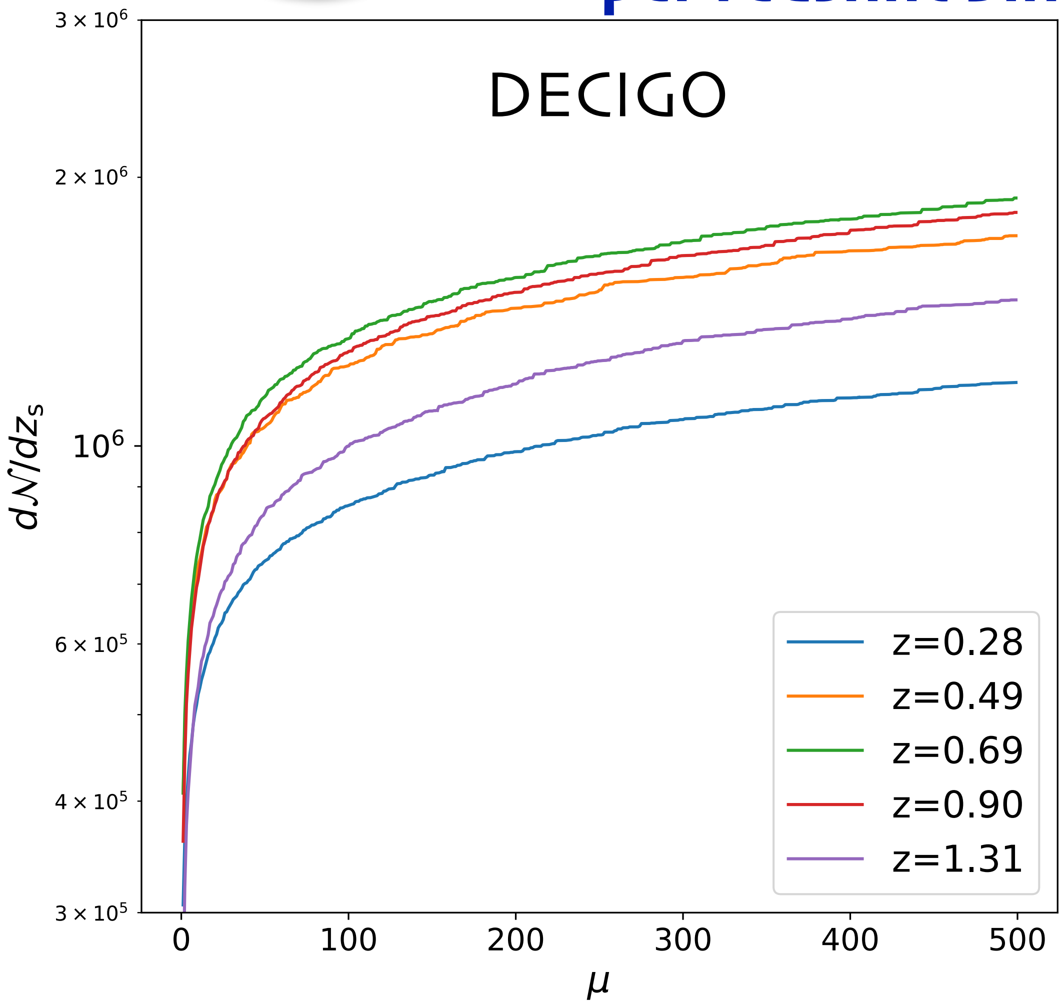


Toscani M. et al. in progress

$$\frac{d\mathcal{N}^{\rm obs}}{dz_{\rm s}} = p(\mu, z_{\rm s})\frac{d\mathcal{N}(\mu)}{dz_{\rm s}}$$

visible events if the magnification is mu per redshift bin





Toscani M. et al. in progress

$$\frac{d\mathcal{N}^{\mathrm{obs}}}{dz_{\mathrm{s}}} = p(\mu, z_{\mathrm{s}})\frac{d\mathcal{N}(\mu)}{dz_{\mathrm{s}}}$$

Preliminary results

-DECIGO will observe few lensed magnified TDEs magnified

-for LISA, unlikely lensed TDEs for MS star

-What about globular TDEs?

Take Home Messages

GWs from TDEs → LISA & Deci-Hertz observatories

Individual TDEs emission → BH and stellar orbit parameters

Background TDEs → BH (IMBH!!) population

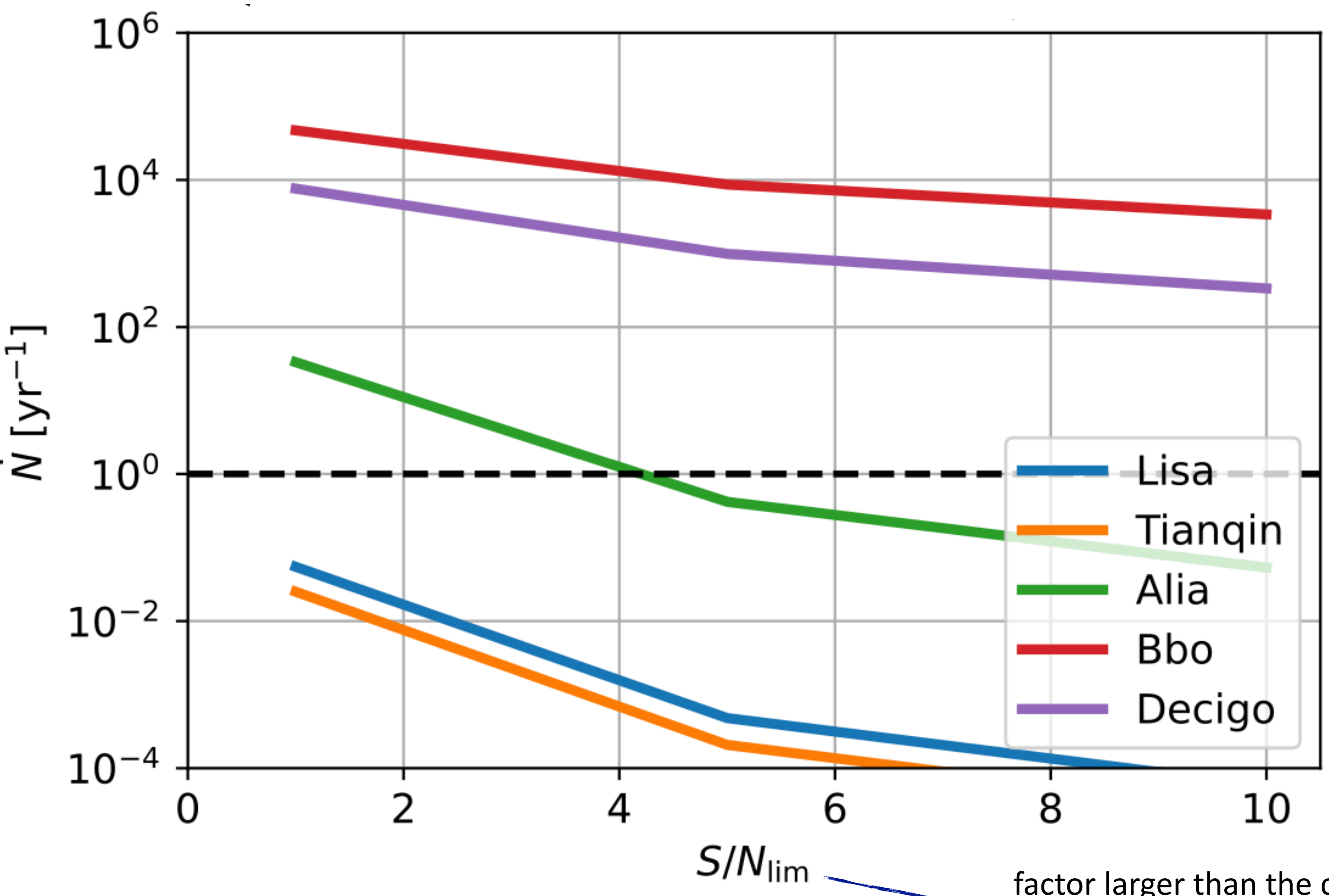
Lensed TDEs → Lens population, multiple images

Thanks For Your Attention!

Fin

BACKUP SLIDES

Pfister H., **Toscani M.** et al. 2021



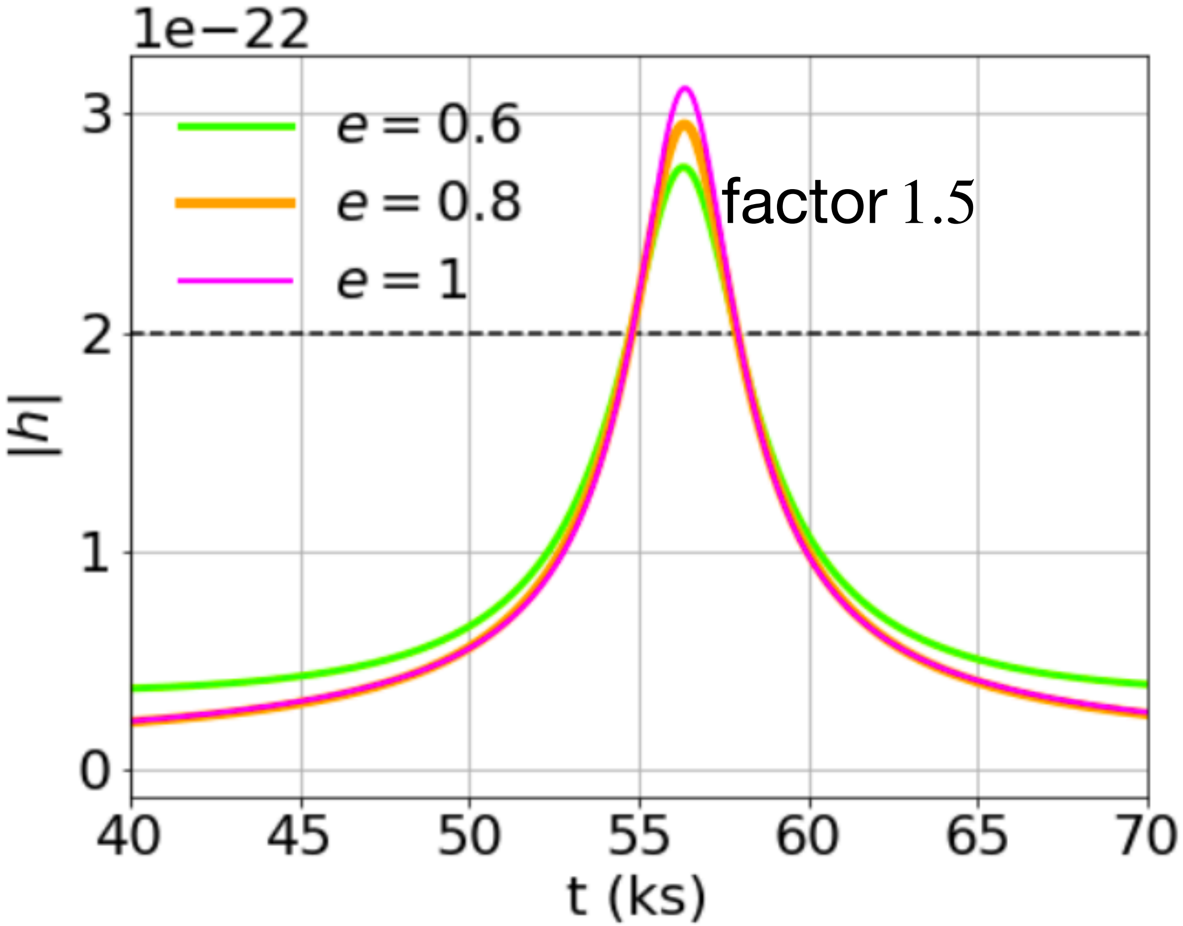
LISA could detect gravitational waves from extreme TDEs (high stellar mass+high beta) up to z=0.1 (400 Mpc)

Following generation of detectors (ALIA, BBO, DECIGO) thousands to millions of TDEs at cosmological redshift

factor larger than the characteristic amplitude noise of the detector at the observed frequency

Toscani M. et al. 2021

Penetration factor 1, orbital inclination angle 0



GW amplitude increases for higher eccentricities