GW to constrain alternative dark energy models

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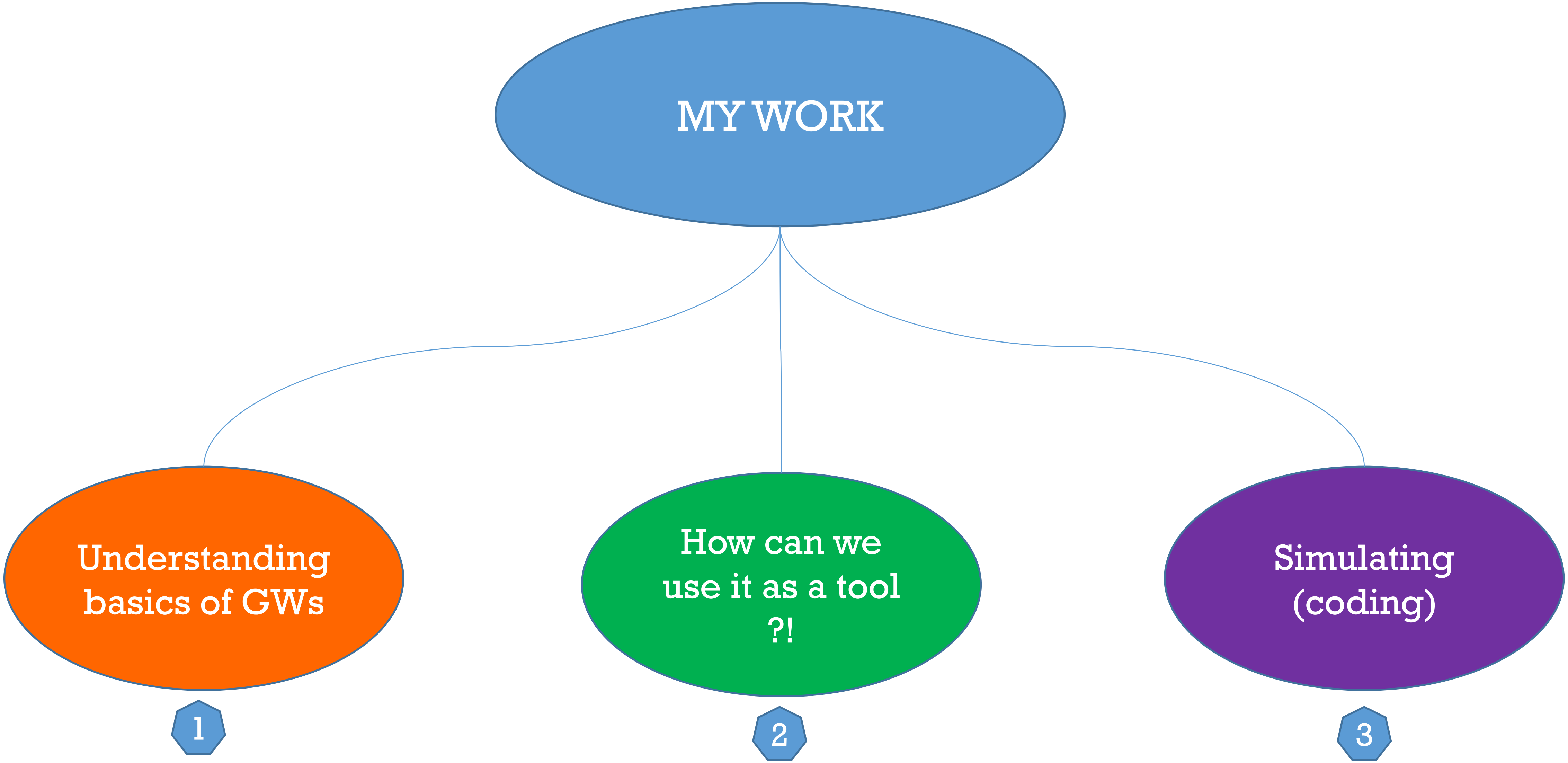
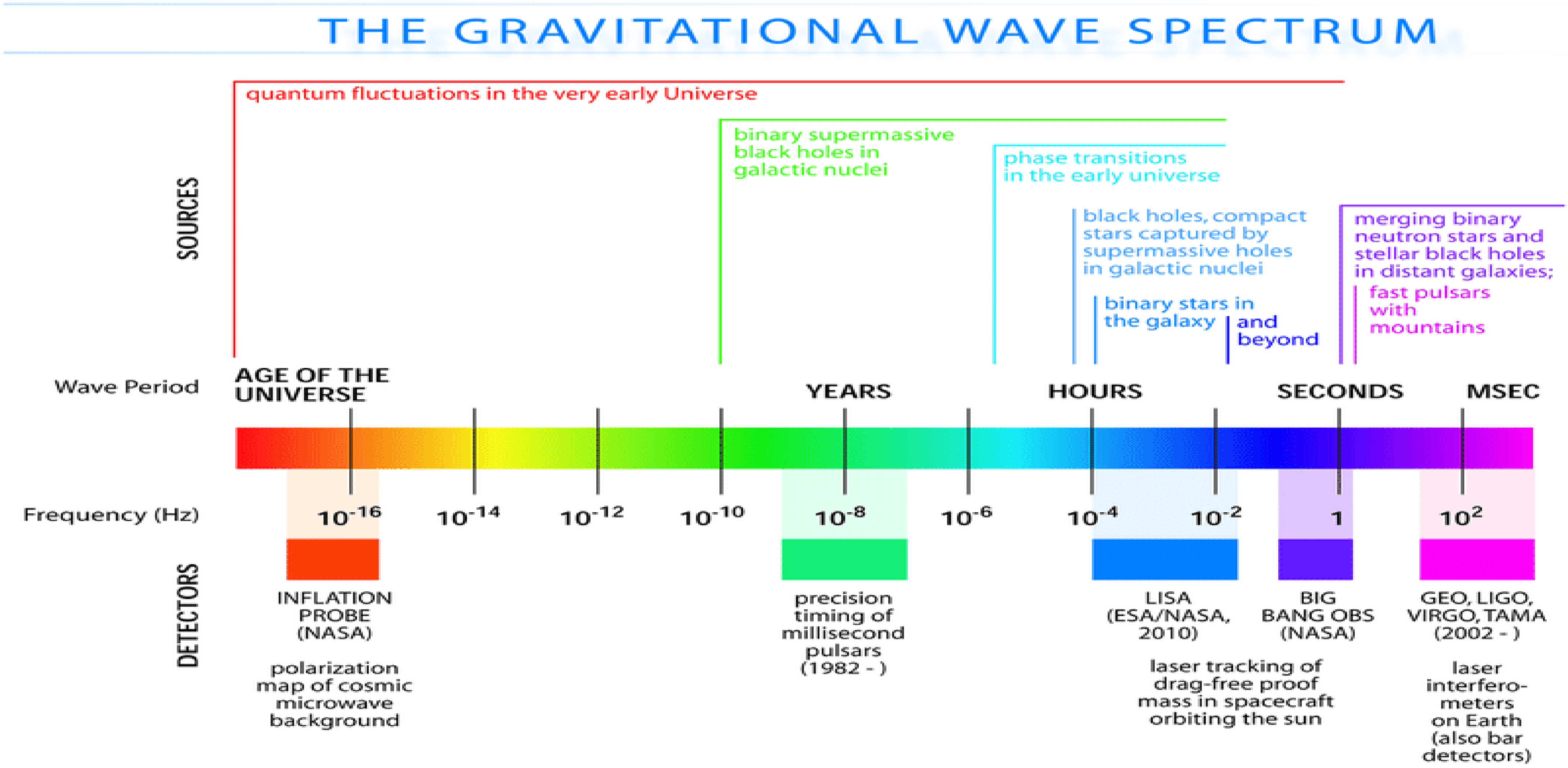
ISRD4


MY WORK
Understanding basics of GWs
How can we use it as a tool ?!
Simulating (coding)
1
2
3

GWs SPECTRUM

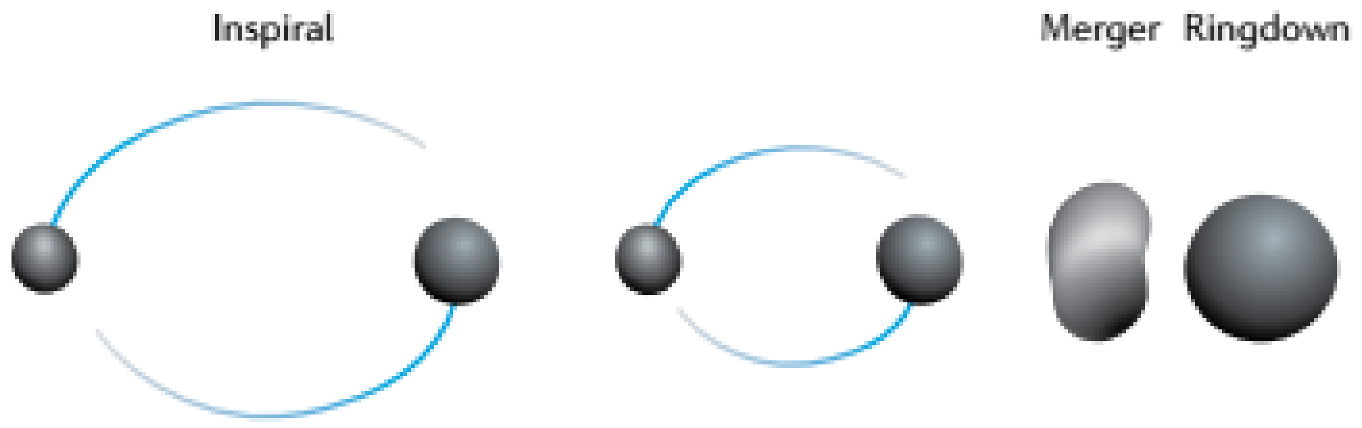


1

Which sources?

BHNS

NSNS

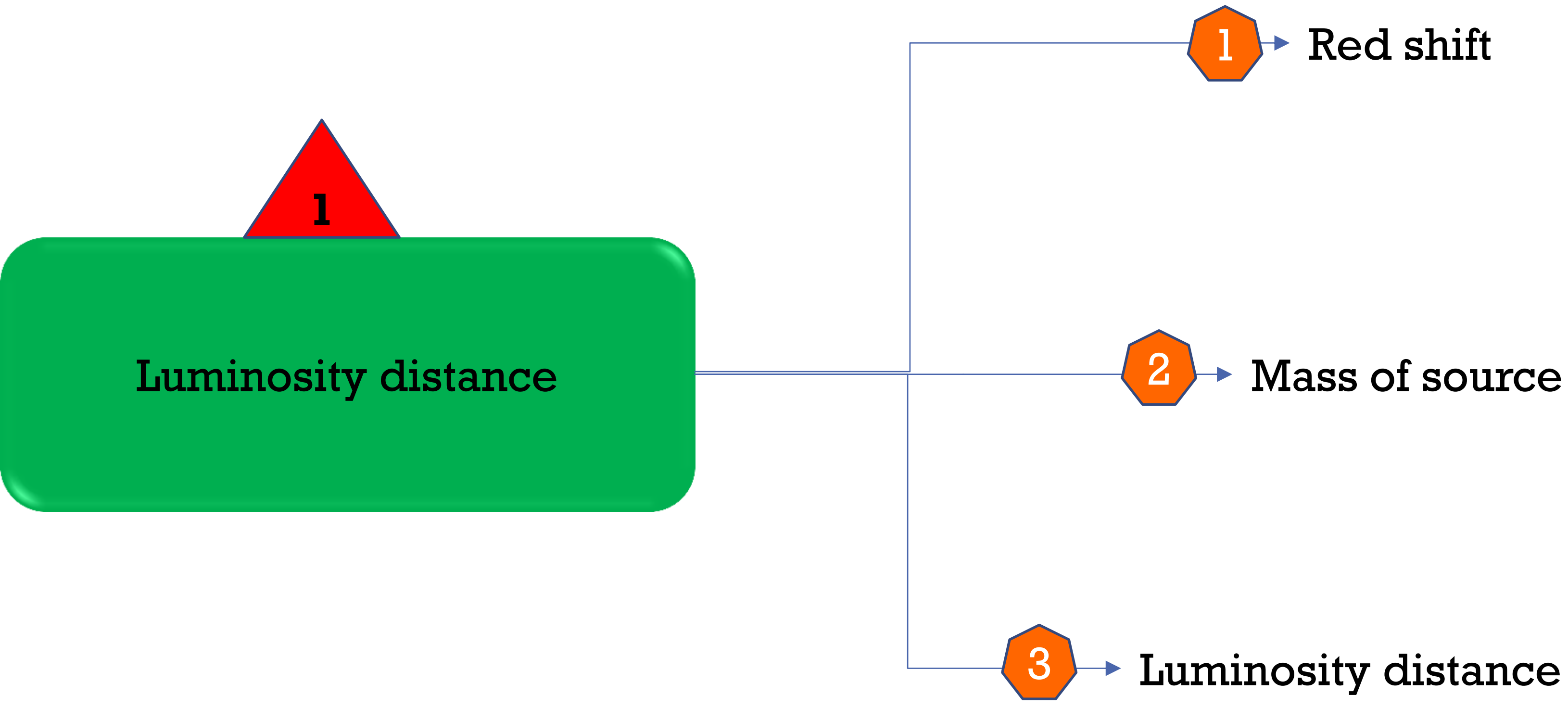


2

What is usage of GWs ?

We can use it to put constrain on cosmological parameters

1. **Luminosity distance**
2. **GWs weak lensing**
3. **GWs strong lensing**
4. **Distance sum rule**


1
Luminosity distance
1
Red shift
2
Mass of source
3
Luminosity distance

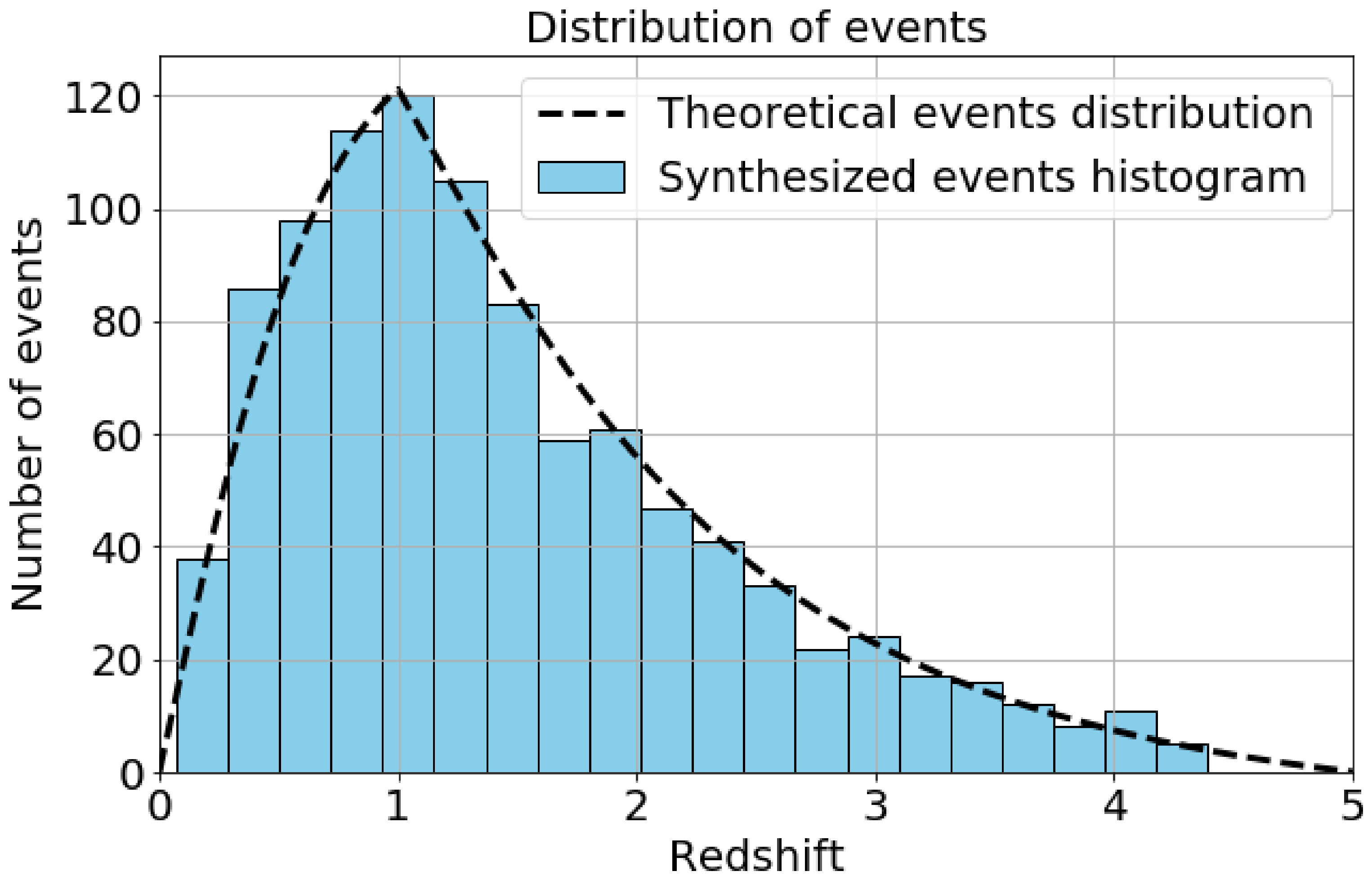
Red shift

$$P(z)\alpha\frac{4\pi d_C^2(z)R(z)}{H(z)(1+z)}$$

where $d_C(z)$ represents the comoving distance at the redshift *z*

***R*(*z*) is the merger rate of binary system (BHNS or BNS)**

$$R(z)=\begin{cases}1+2z, & z\leq 1,\\ \frac{3}{4}(5-z), & 1<z<5,\\ 0\,, & z\geq 5,\end{cases}$$



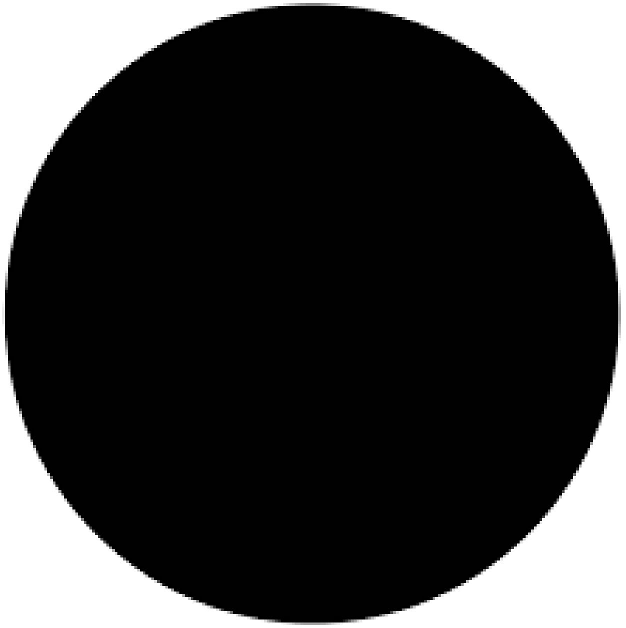
DISTRIBUTION OF EVENTS

$$P(z) \alpha \frac{4\pi d_C^2(z) R(z)}{H(z)(1+z)}$$

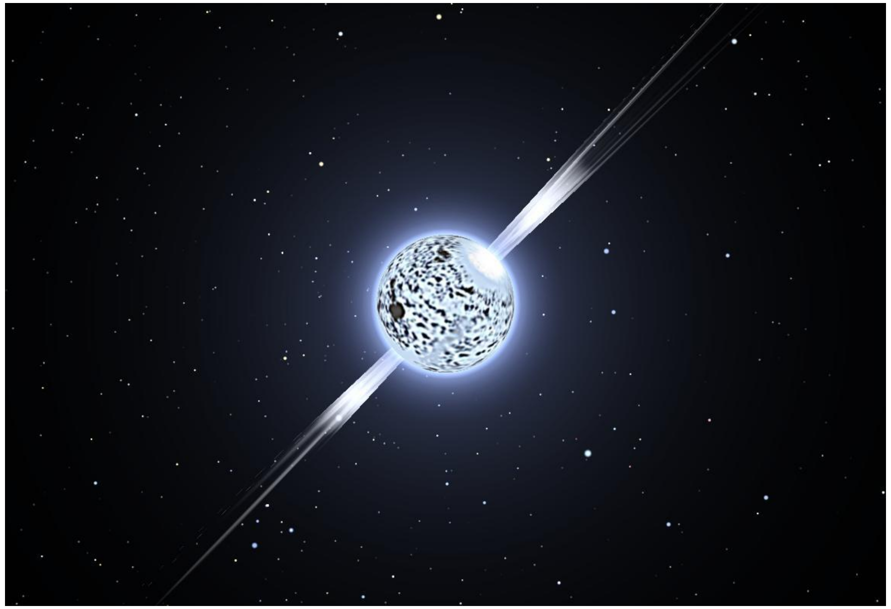
$$R(z) = \begin{cases} 1 + 2z, & z \leq 1, \\ \frac{3}{4}(5 - z), & 1 < z < 5, \\ 0\,, & z \geq 5, \end{cases}$$

[3]

Mass of sources



[3-10] $M_\odot$



[1-2]$M_\odot$

Luminosity distance & GW

$$h(t) = F_+(\theta,\varphi,\psi)h_+(t) + F_\times(\theta,\varphi,\psi)h_\times(t)$$

ψ is the polarization angle, and (θ, φ) are angles describing the location of the source in the sky, relative to the detector .

Beam pattern functions

$$F_+^{(1)}(\theta,\varphi,\psi) = \frac{\sqrt{3}}{2}\left[\frac{1}{2}(1+cos^2\theta)\cos(2\varphi)\cos(2\psi) - \cos(\theta)\sin(2\varphi)\sin(2\psi)\right]$$

$$F_\times^{(1)}(\theta,\varphi,\psi) = \frac{\sqrt{3}}{2}\left[\frac{1}{2}(1+cos^2\theta)\cos(2\varphi)\sin(2\psi) + \cos(\theta)\sin(2\varphi)\cos(2\psi)\right]$$

Fourier space

$$H(f) = \boldsymbol{A} f^{-7/6} \exp[i(2\pi f t_0 - \frac{\pi}{4} + 2\psi\left(\frac{f}{2}\right) - \varphi_{(2,0)})]$$

$$A = \frac{1}{d_L}\sqrt{F_+^2(1+cos^2(\iota))^2 + F_\times^2 cos^2(\iota)} \times \sqrt{5\pi/96}\pi^{-7/6} M_c^{5/6}$$

[3-10] $M_\odot$

Black hole

[1-2]$M_\odot$

Neutron star

$$M_c = M\eta^{3/5}$$

$$M = m_1 + m_2$$

$$\eta = m_1 m_2 / M^2$$

Luminosity distance

$$d_L = \begin{cases} \dfrac{1+z}{H_0\sqrt{\Omega_k}} \sinh\left(\Omega_k \displaystyle\int_0^z \dfrac{d\tilde{z}}{E(z)}\right) & \Omega_k > 0 \\ \dfrac{1+z}{H_0} \displaystyle\int_0^z \dfrac{d\tilde{z}}{E(z)} & \Omega_k = 0 \\ \dfrac{1+z}{H_0\sqrt{|\Omega_k|}} \sin(\sqrt{|\Omega_k|} \displaystyle\int_0^z \dfrac{d\tilde{z}}{E(z)}) & \Omega_k < 0 \end{cases}$$

$$E(z) = H(z)/H_0$$

$$d_L(z) = (1+z)\int_0^z \frac{d\acute{z}}{E(\acute{z})}$$

$$H(z)^2 = H_0^2 \left\{ (1-\Omega_m-\Omega_k) exp\left[3\int_0^z \frac{1+\omega(\tilde{z})}{1+\tilde{z}} d\tilde{z}\right] + \Omega_m(1+z)^3 + \Omega_k(1+z)^2 \right\}$$

Where is the usage of GWs ?

$$\sigma_{d_L} = \sqrt{(\sigma_{d_L}^{\text{inst}})^2 + (\sigma_{d_L}^{\text{lens}})^2}$$

$$\sigma_{d_L}^{\text{inst}} \simeq \frac{2d_L}{\rho}.$$

$$\sigma_{d_L}^{\text{lens}}/d_L = 0.05z.$$

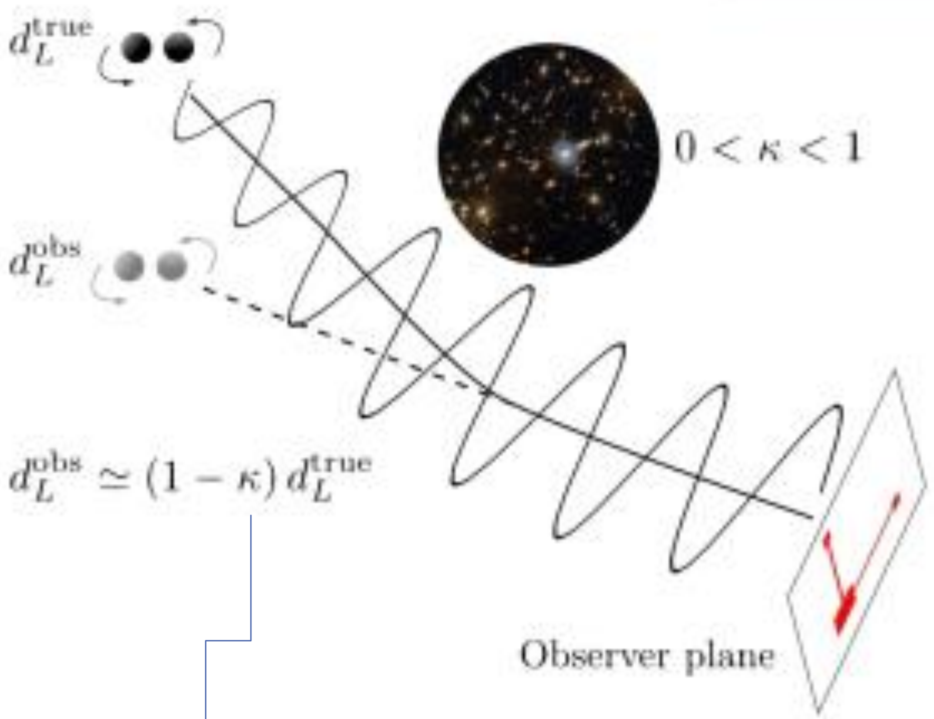
$$\rho^{(i)} = \sqrt{\langle \mathcal{H}^{(i)}, \mathcal{H}^{(i)} \rangle};$$

$$\langle a, b \rangle = 4 \int_{f_{\text{lower}}}^{f_{\text{upper}}} \frac{\tilde{a}(f)\tilde{b}^*(f) + \tilde{a}^*(f)\tilde{b}(f)}{2} \frac{df}{S_h(f)},$$

$$H(f) = \boldsymbol{A} f^{-7/6} \exp[i(2\pi f t_0 - \frac{\pi}{4} + 2\psi\left(\frac{f}{2}\right) - \varphi_{(2,0)})]$$

2

Weak lensing



$$d_L^{obs} = \frac{1}{\sqrt{\mu}} d_L^{true} \simeq (1-\kappa) d_L^{true} \,.$$

$$\mu \approx 1 + 2\kappa \,,$$

magnification of both electromagnetic and gravitational radiation in the geometric optics regime

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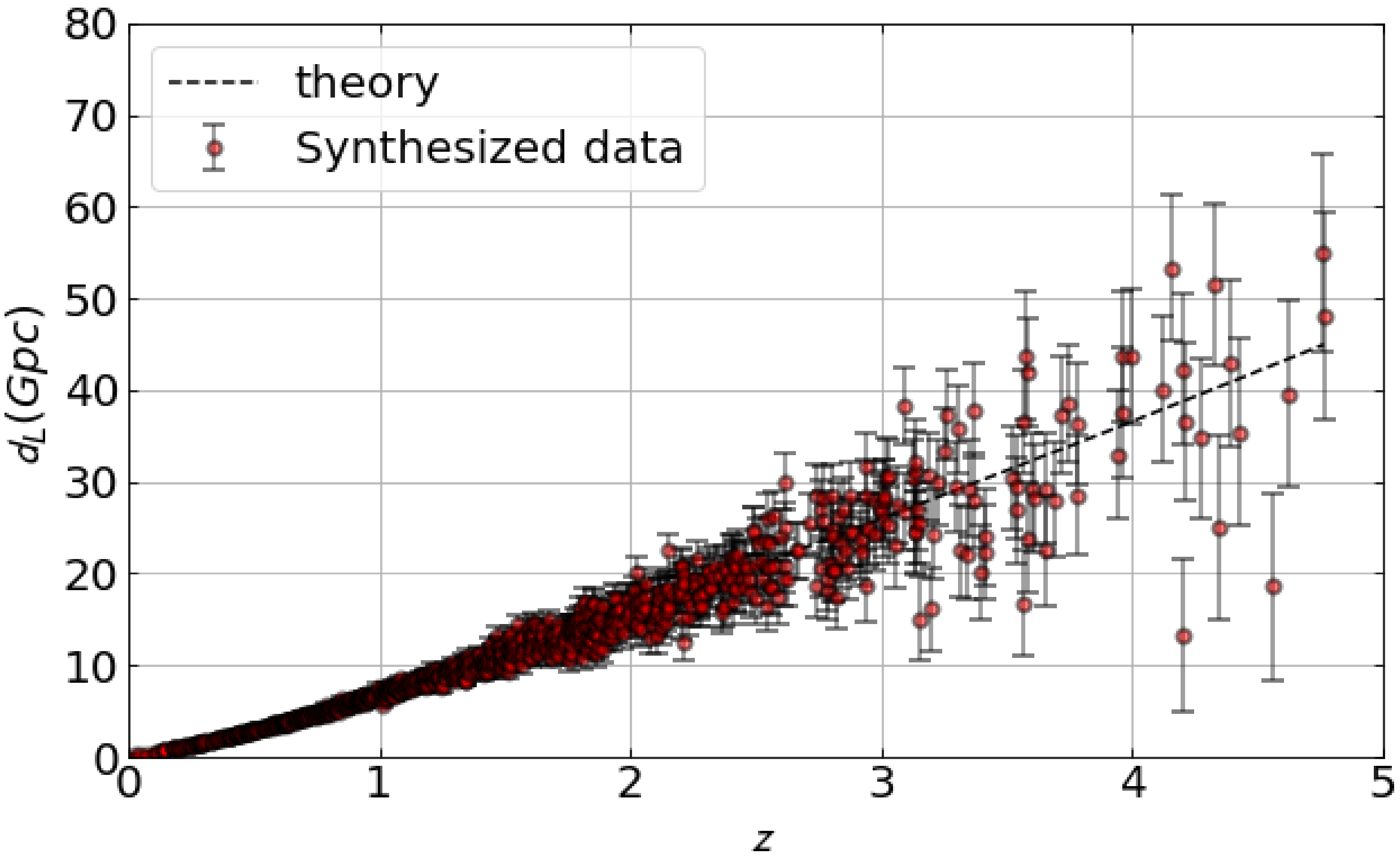
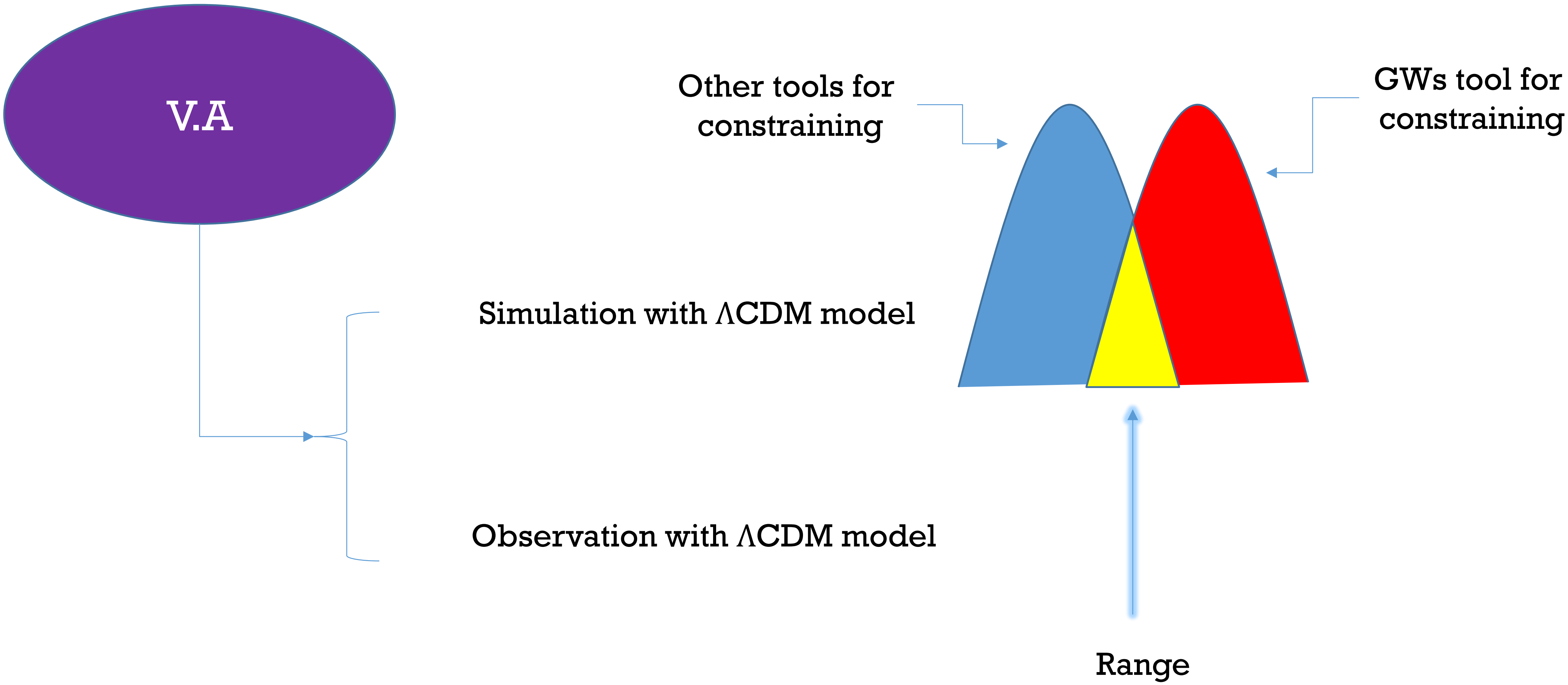
where κ is the lensing convergence, a weighted projection of density perturbations along the line-of-sight



LUMINOSITY DISTANCES

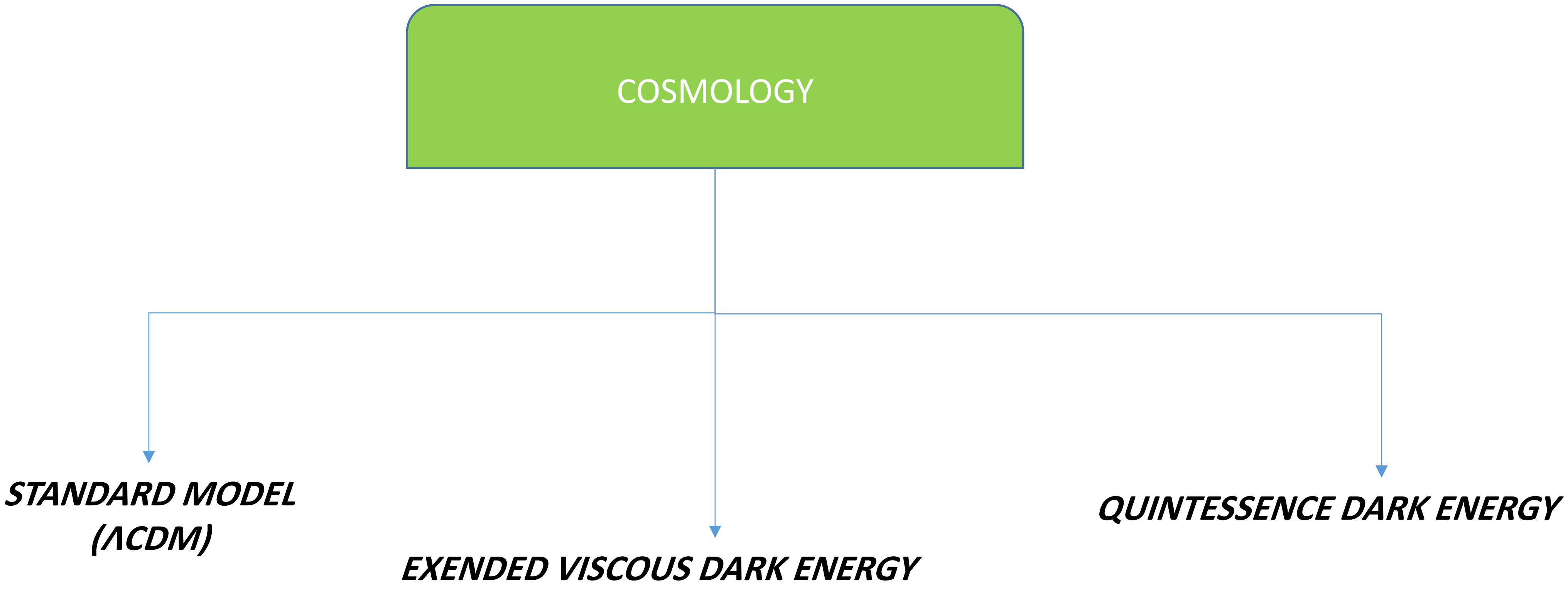
$$\sigma_{d_L}^{\text{inst}} \simeq \frac{2d_L}{\rho}.$$

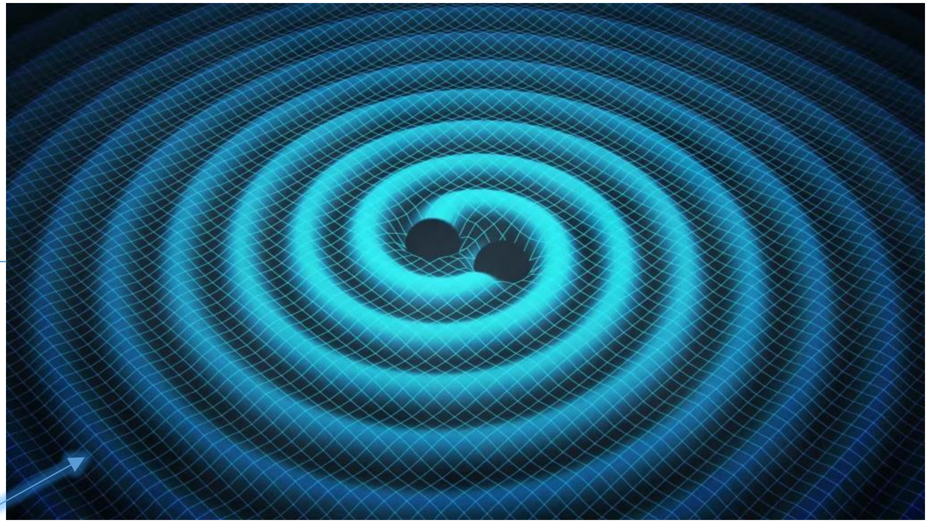
$$\sigma_{d_L}^{\text{lens}}/d_L = 0.05z.$$


V.A
Other tools for constraining
GWs tool for constraining
Simulation with ΛCDM model
Observation with ΛCDM model
Range

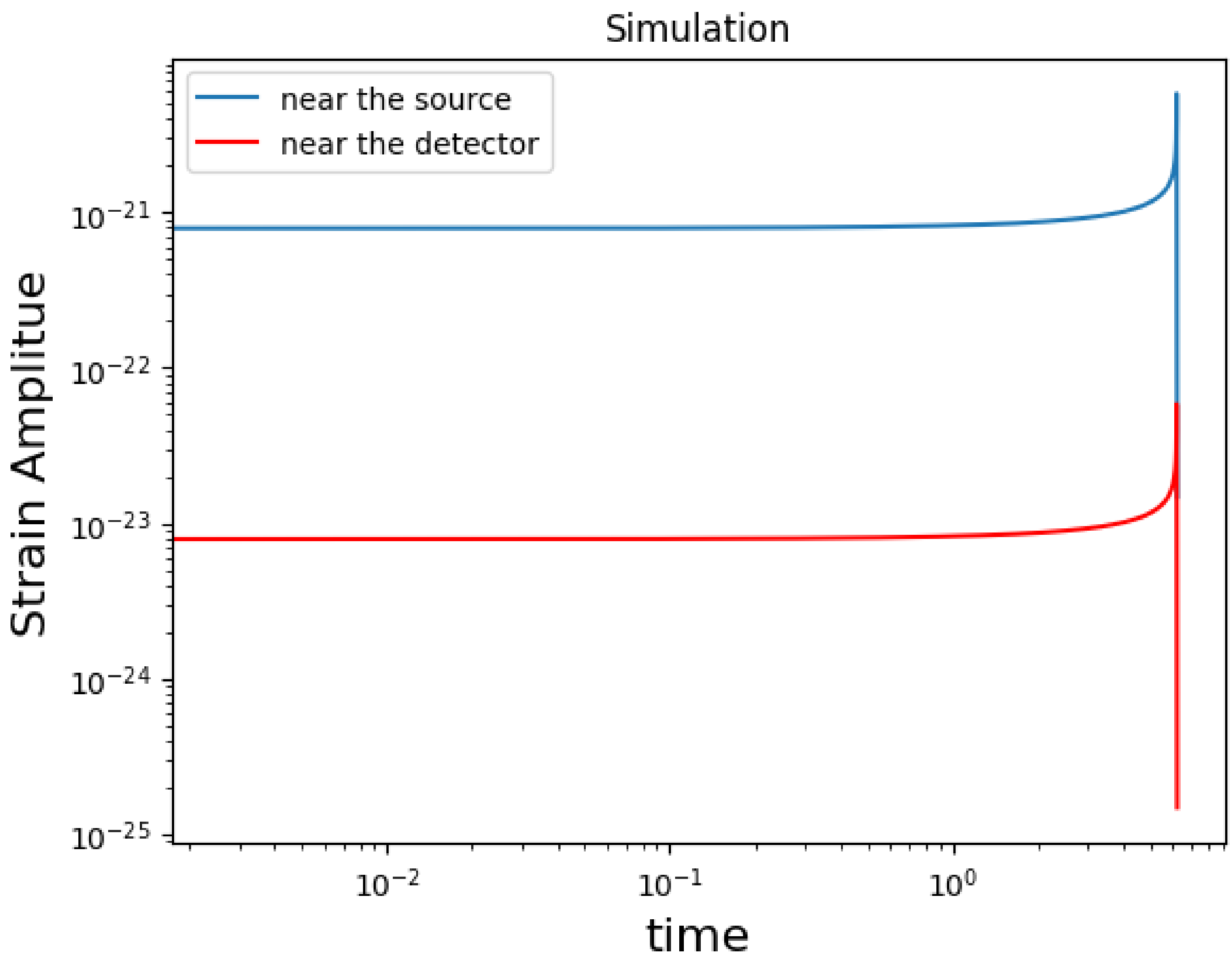
DARK ENERGY

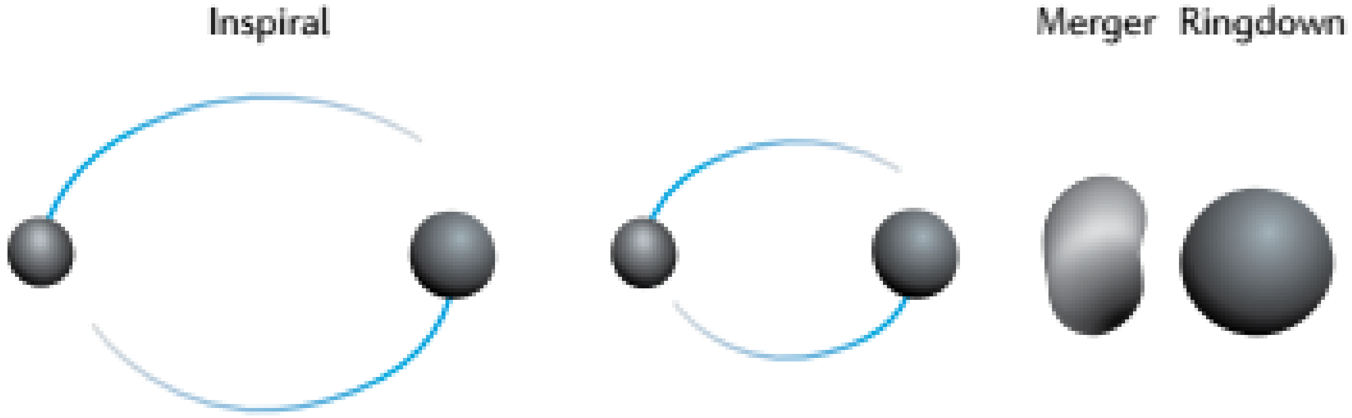
DARK ENERGY

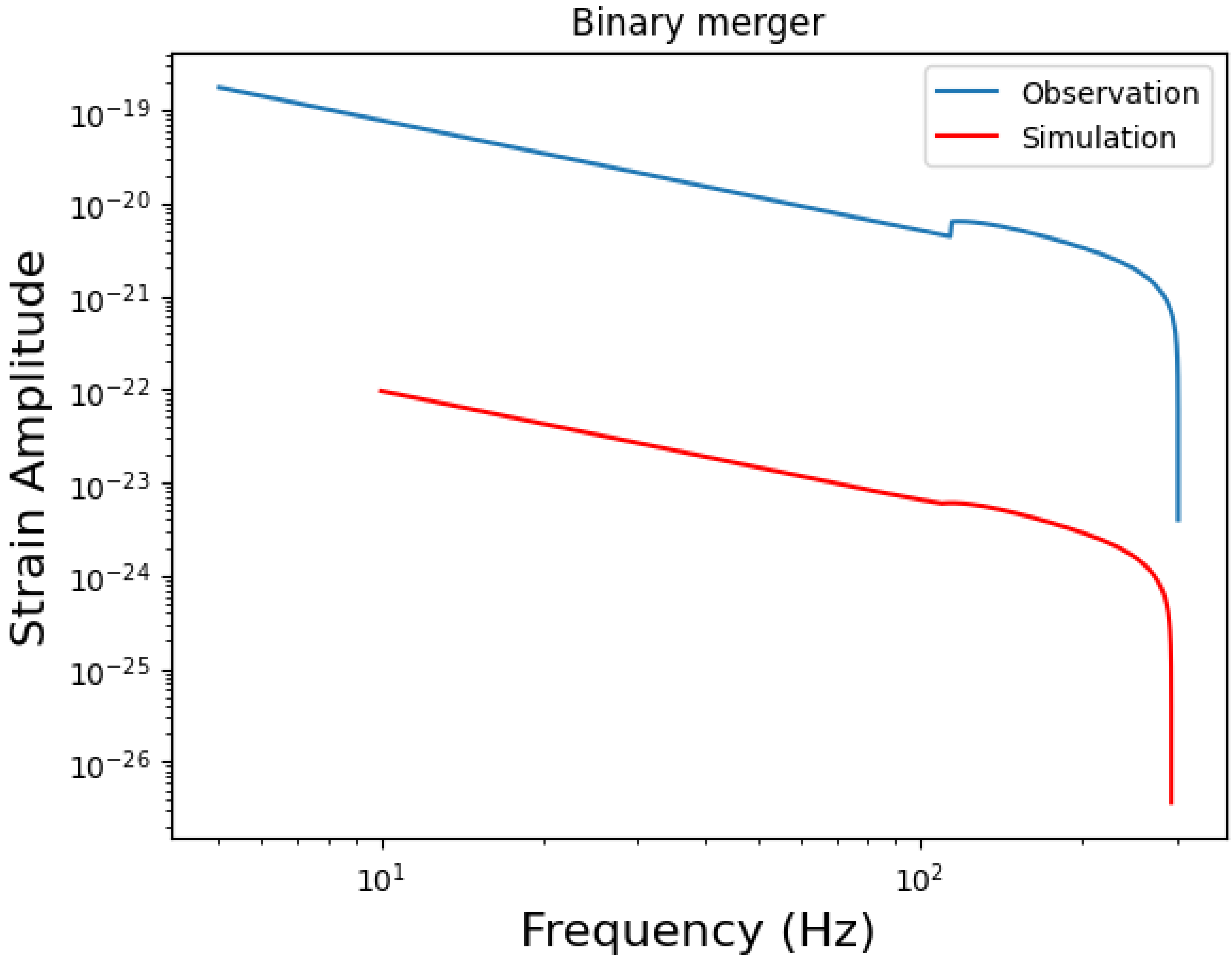

COSMOLOGY
STANDARD MODEL
(ΛCDM)
EXENDED VISCOUS DARK ENERGY
QUINTESSENCE DARK ENERGY



Cosmological model

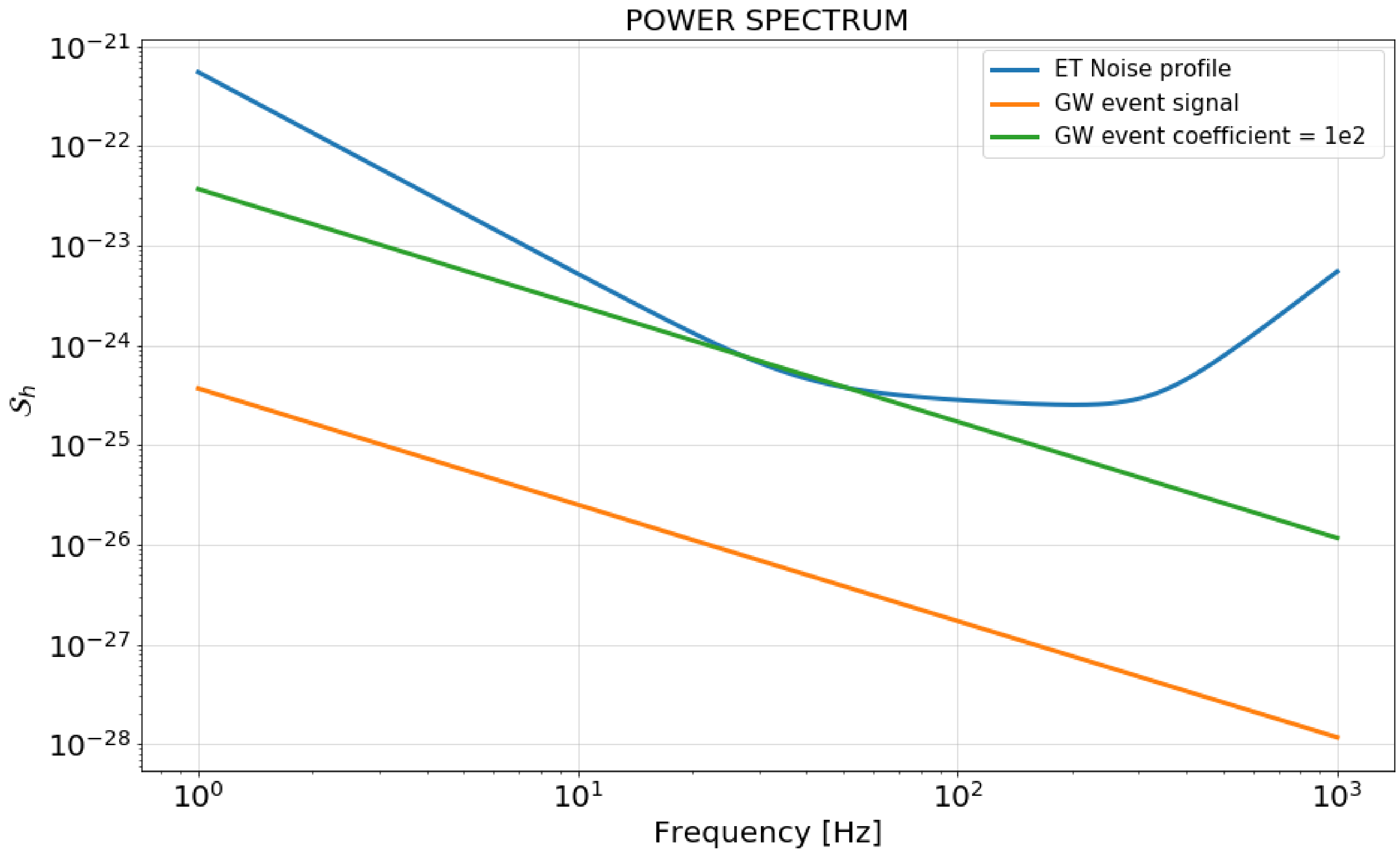

Simulation
near the source
near the detector
Strain Amplitue
time
10^{-21}
10^{-22}
10^{-23}
10^{-24}
10^{-25}
10^{-2}
10^{-1}
10^{0}


Inspiral
Merger
Ringdown



Binary merger
Observation
Simulation
Strain Amplitude
10^{-19}
10^{-20}
10^{-21}
10^{-22}
10^{-23}
10^{-24}
10^{-25}
10^{-26}
10^{1}
10^{2}
Frequency (Hz)

POWER SPECTRUM



What next :

- Use different D.E models and put constrain on them.
- Complete writing section of my thesis.


THANKS FOR
YOUR ATTENTION

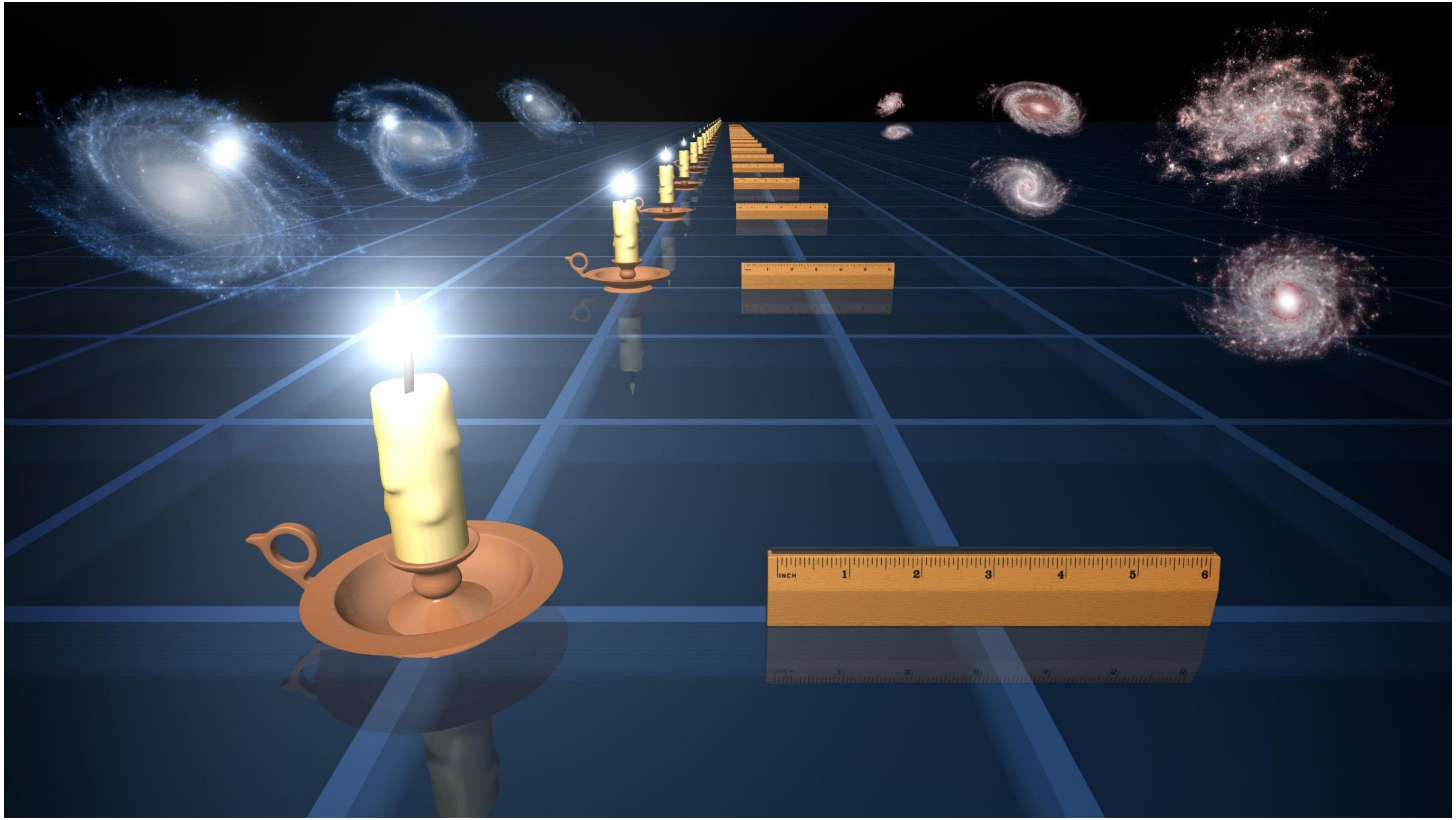
INTENSIVE REPORT RELATED ARTICLES

[1]: https://doi.org/10.1088/1475-7516/2023/03/047
[2]: https://doi.org/10.3847/2041-8213/acda9a
[3] :https://doi.org/10.1038/s42254-021-00303-8
[4]:https://doi.org/10.3847/2041-8213/acdac6
[5]:arXiv:2306.16220v2
[6] : http://www.njp.org/doi:10.1088/1367-2630/7/1/204
[7] :10.1103/PhysRevResearch.4.013247
[8]: EPJC-20-11-123
[9]: https://doi.org/10.1038/s42254-021-00303-8
[10] : http://www.njp.org/doi:10.1088/1367-2630/7/1/204
[12]: EPJC-20-11-123
[11] :10.1103/PhysRevResearch.4.013247
[13] : arXiv:1608.08008v2
[14] :arXiv:2202.09726v3
[15] : arXiv:2009.09754v1
[16] : arXiv:2109.07537v2

Rulers

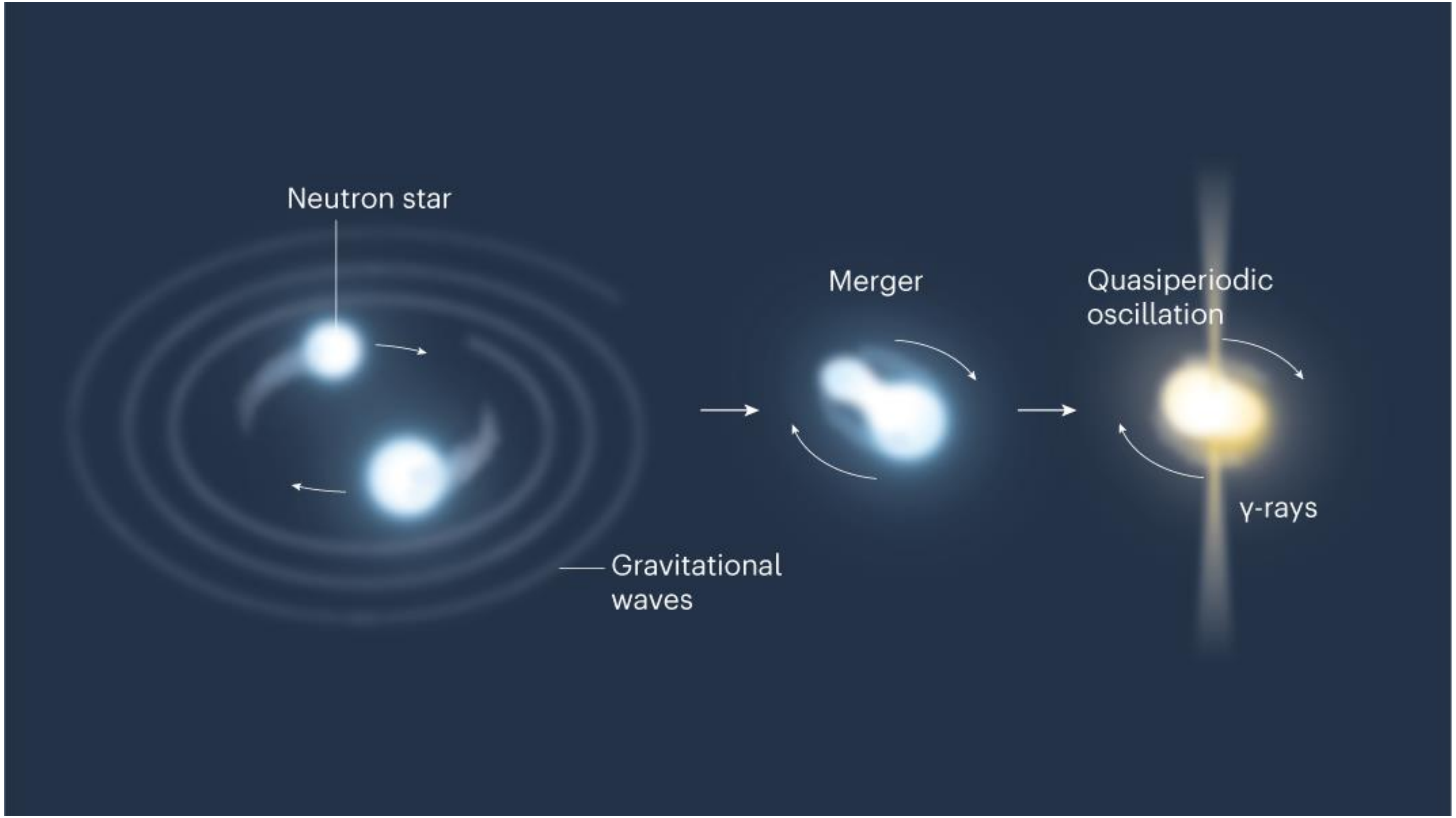
- Standard candles
- Standard sirens
- Standard rulers

Standard candles



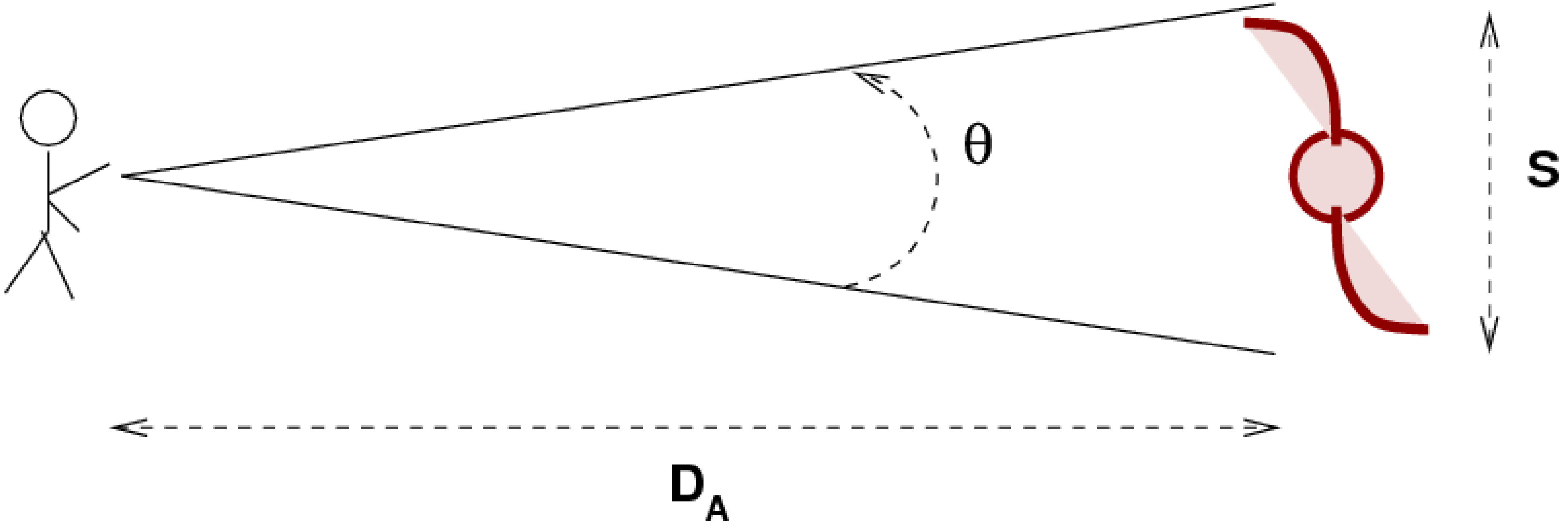
$$F = \frac{L}{4\pi d^2},$$

Standard sirens

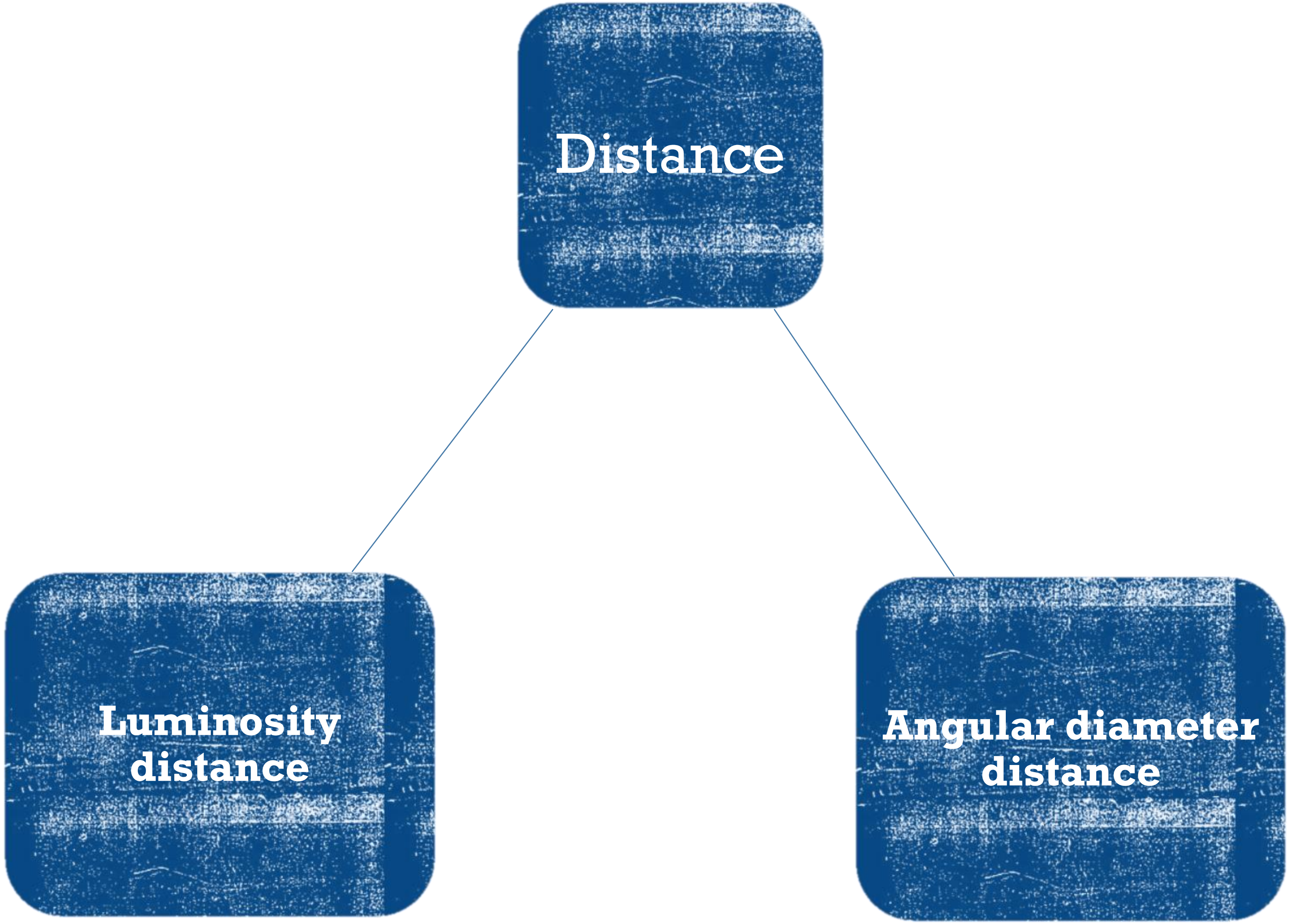


$$F = \frac{L}{4\pi d^2},$$

Standard ruler



$$d_A = \frac{l}{\theta}.$$


Distance
Luminosity distance
Angular diameter distance