

Mass-Sheet degeneracy in Gravitational Wave Lensing

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1. Mass-Sheet Degeneracy

The MSD is a well-known problem in lensing of light.

It consists on [1]

- Scaling of lens mass

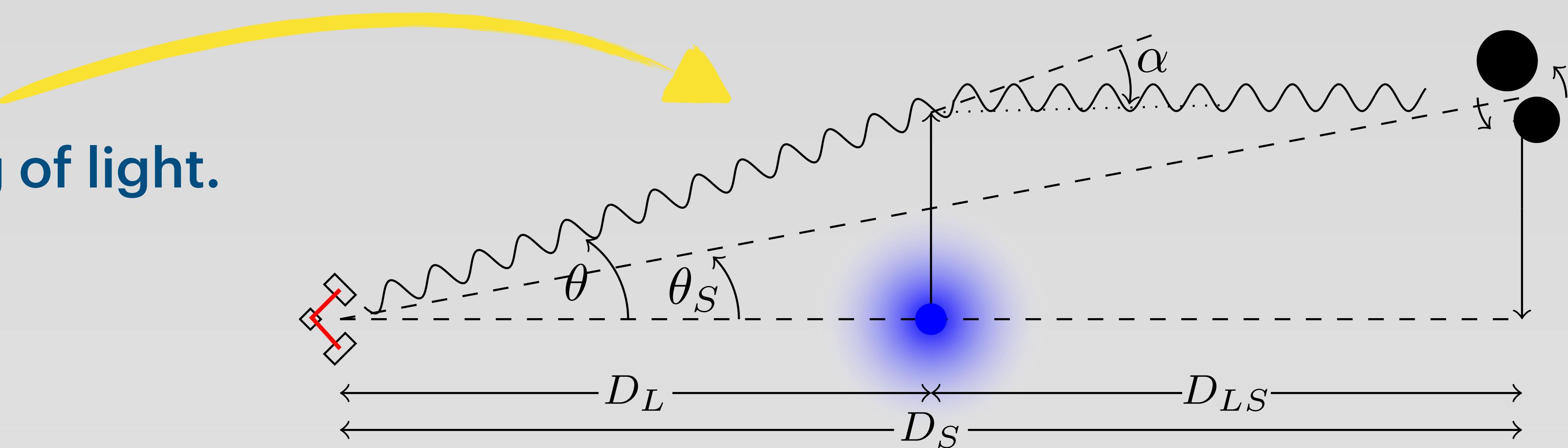
(κ - surface mass density)

$$\kappa \rightarrow \kappa_\lambda = \lambda \kappa + (1 - \lambda)$$

- Scaling of angles

$$\vec{\alpha} \rightarrow \vec{\alpha}_\lambda = \lambda \vec{\alpha} + (1 - \lambda) \vec{\theta}$$

$$\vec{\theta}_S \rightarrow \vec{\theta}_{S,\lambda} = \lambda \vec{\theta}_S$$



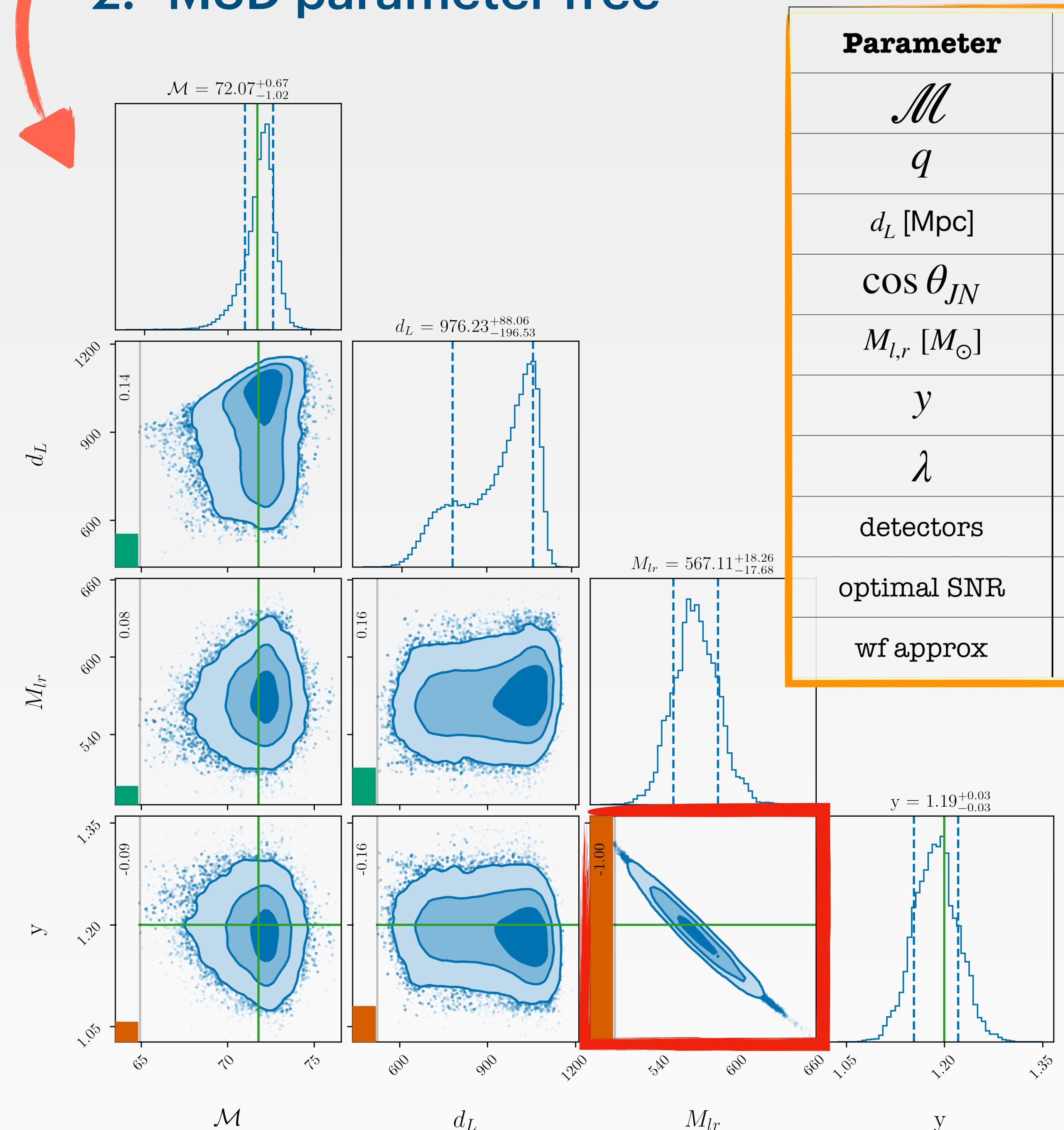
2. Problem

- Observables are preserved!
- Biased estimations of lens parameters
- Biased estimation of cosmological parameter

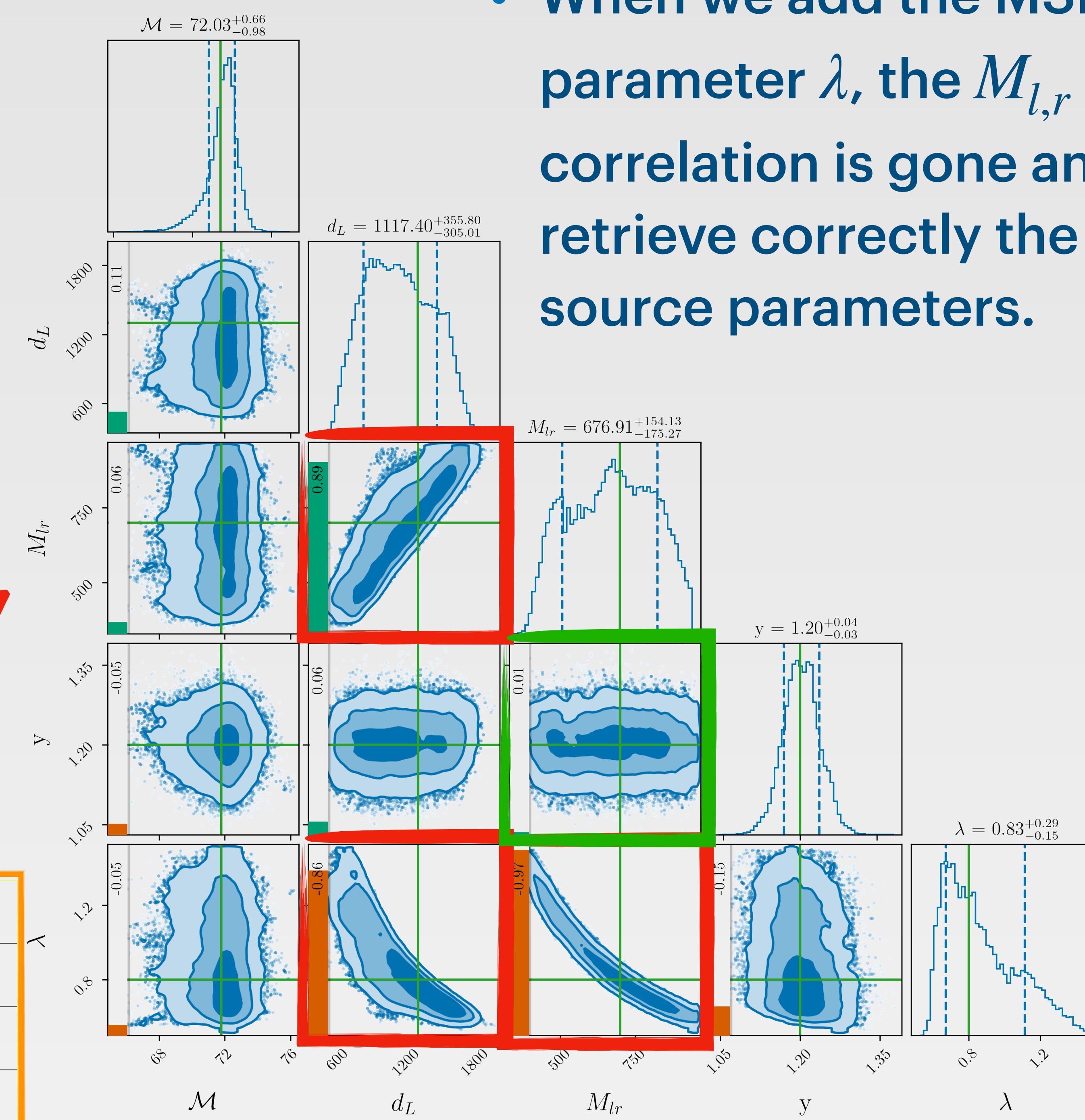
3. Method

Exploiting the work done in [2], we:

- Rewrite the amplification factor [3] to include the MSD parameter: $\tilde{h}_L(f) = \tilde{h}(f) \cdot F(f, y, \lambda)$
- Simulate a BBH lensed event with $\lambda \neq 1$
- Study the event through 2 PE analysis:
 - MSD parameter fixed to $\lambda = 1$
 - MSD parameter free



Parameter	Value
\mathcal{M}	71.78
q	0.94
d_L [Mpc]	1300
$\cos \theta_{JN}$	0.95
$M_{l,r}$ [M_\odot]	700
y	1.2
λ	0.8
detectors	H1,L1,V1
optimal SNR	78
wf approx	IMRPhenomXP



4. Analysis

- In the “standard” PE analysis, the lens mass and the source distance are biased, as we can see from the first plot (bottom left).

- When we add the MSD parameter λ , the $M_{l,r} - y$ correlation is gone and we retrieve correctly the lens and source parameters.

5. Conclusions

Studying the MSD is important to:

- set correct uncertainties of lens parameters
- characterise lens model
- astrophysical and cosmological studies

In this work we were able to properly recognise an external presence of mass and reconstruct the lens parameters correctly.

Bibliography

- [1] E. E. Falco, M. V. Gorenstein, and I. I. Shapiro, ApJ289, L1 (1985)
- [2] P. Cremonese, J.M. Ezquiaga, V. Salzano, Phys. Rev. D 104 (2021) 2, 023503
- [3] T. T. Nakamura and S. Deguchi, “Progress of Theoretical Physics Supplement” 133, 137 (1999).

