

# **Strong Gravitational Lensing of Gravitational Waves by Galaxy Clusters**

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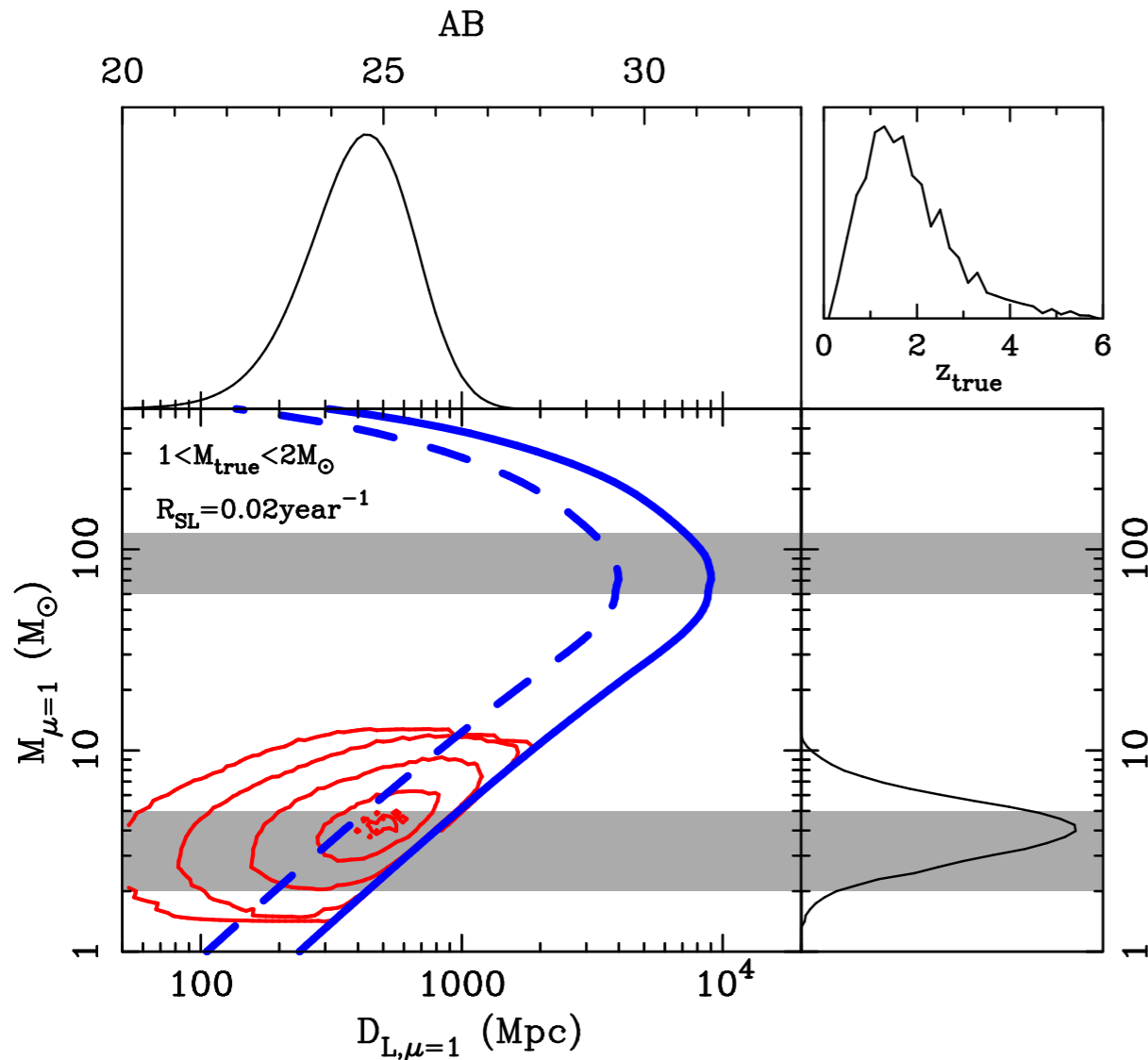
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# Strong lensing modifies interpretation of GW sources

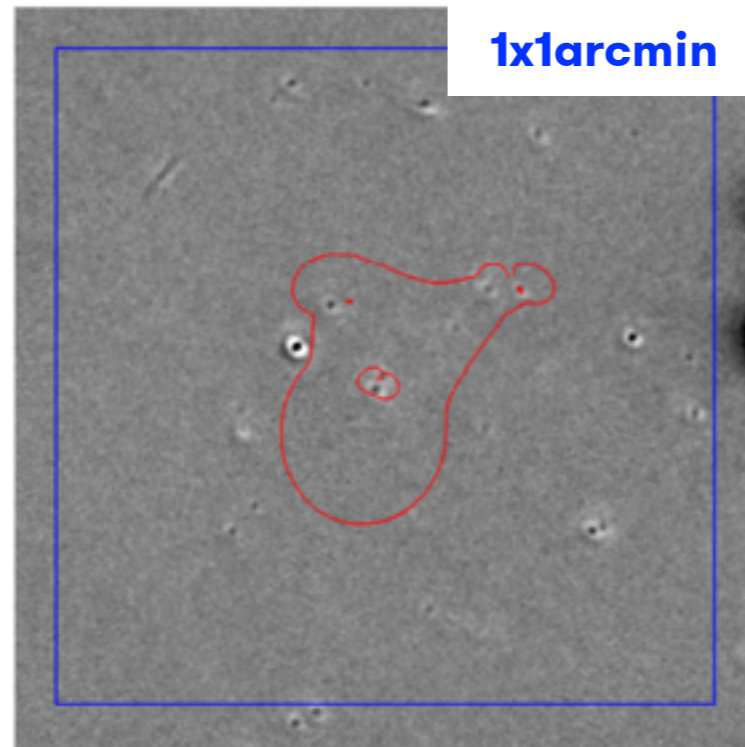
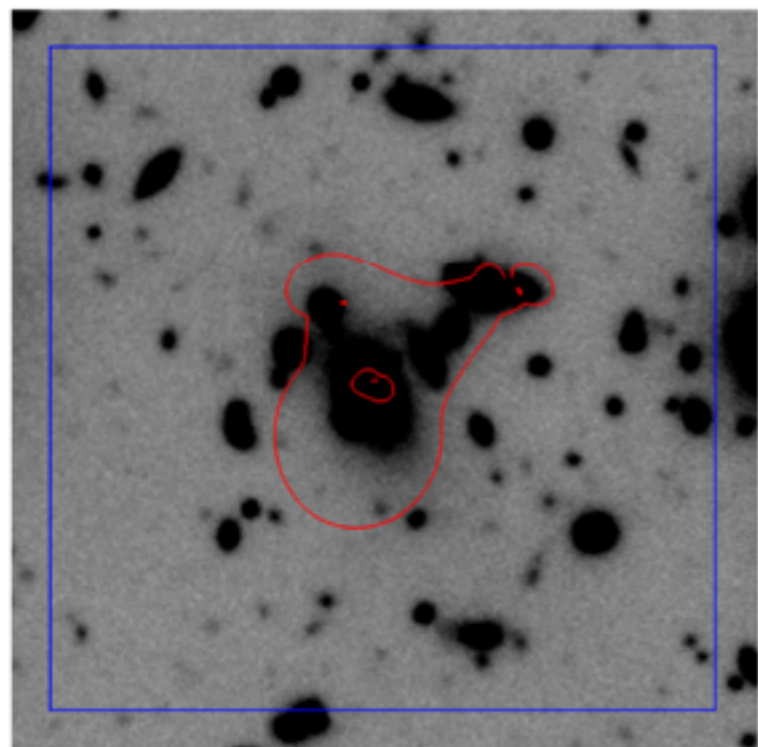
Strain amplitude  $\propto D_L^{-1} |\mu|^{0.5}$

Rest frame mass  $\propto (1+z)^{-1}$

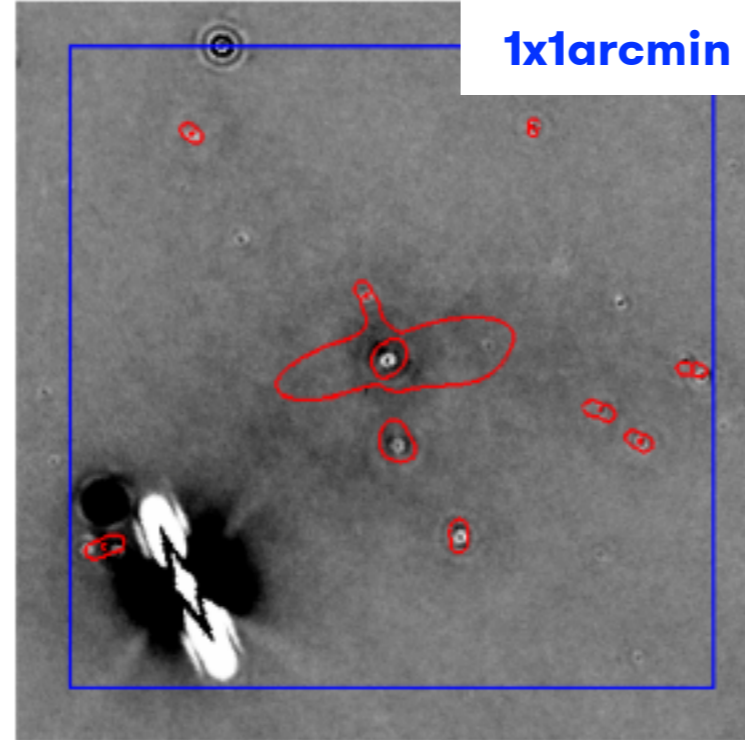
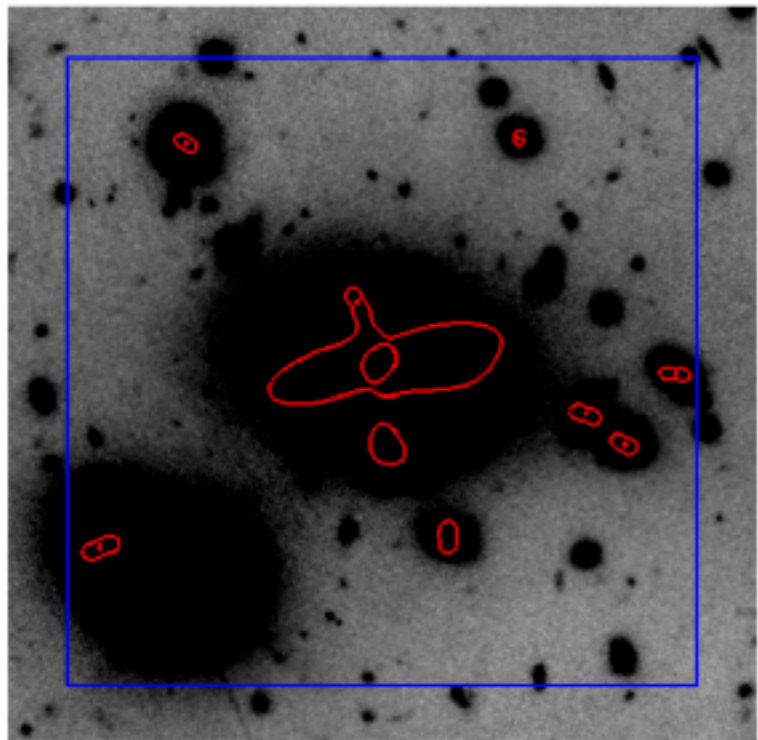


- rate of NS-NS mergers evolves following SFRD evolution (Madau+2014)
- $\mu = 100$
- GW170817-like counterpart
- AB magnitudes are in the i-band within 3 Earth-frame days of LIGO discovery
- Optical depth to strong lensing is equally split between clusters and galaxies

# Strong lensing clusters as only viable line of sight



**SMACS0304  
GMOS  
imaging and  
difference  
image**



**A3084  
GMOS  
imaging and  
difference  
image**

no transients at  $m < 25$

# Current and future scenario

- **Today the only feasible approach is to target powerful gravitational clusters located within the relevant sky localisations**
- **LSST will cover a typical 90% GW localisation map with 12 pointings**
- **We advocate for an LSST ToO programme that allows observations deeper than the nominal Wide-Fast-Deep single visit depth of AB~24 (Smith+19, LSST white paper)**
- **4.5 hours per trigger (3 visits in two filters), 1-2 trigger each 5 years**

# To find out more..

- **What if LIGO's gravitational wave detections are strongly lensed by massive galaxy clusters?**  
G. P. Smith, M. Jauzac, J. Veitch, W. M. Farr, R. Massey, J. Richard, 2018, MNRAS, 475, 3823, arXiv:1707.03412
- **Strong-lensing of Gravitational Waves by Galaxy Clusters**  
G. P. Smith, C. P. L. Berry, M. Bianconi, W. M. Farr, M. Jauzac, R. Massey, J. Richard, A. Robertson, K. Sharon, A. Vecchio, J. Veitch, Proceedings IAU Symposium No. 338, 2018, Gravitational Wave Astrophysics, arXiv:1803.07851
- **Deep and rapid observations of strong-lensing clusters within the sky-localisation of GW170814**  
G. P. Smith, M. Bianconi, M. Jauzac, J. Richard, A. Robertson, C. P. L. Berry, R. Massey, K. Sharon, W. M. Farr, J. Veitch, 2019, MNRAS 485, 5180, arxiv:1805.07370
- **Discovery of strongly-lensed Gravitational Waves - Implications for the LSST Observing Strategy**  
G. P. Smith, A. Robertson, M. Bianconi, M. Jauzac (on behalf of the LSST Strong Lensing Science Collaboration and the Gravitationally Lensed Gravitational Wave Hunters) xsarXiv:1902.05140