Gravitationally lensed BNS/kilonova discovery as motivation for including p_{gap} in low latency alerts from LVK in O4

Graham Smith

LSST Strong Lensing Science Collaboration Co-chair
LSST:UK Commissioning Scientist
gps@star.sr.bham.ac.uk

in collaboration with:
Matteo Bianconi, Mathilde Jauzac, **Guillaume Mahler**, Richard Massey, Matt Nicholl, Johan Richard, **Evan Ridley**, **Andrew Robertson**, **Dan Ryczanowski**, Keren Sharon, **Joshua Smith**; Timo Anguita, Simon Birrer, Aprajita Verma, and LSST colleagues

THE ROYAL SOCIETY
LEVERHULME TRUST
UKRI Science and Technology Facilities Council
Royal Astronomical Society

Towards robust discovery of lensed GWs

Aim:

- Multiple detections of the same gravitational wave and any accompanying electromagnetic signal from a distant source that is gravitationally lensed

Challenges:

- Strong evidence is required to overcome the **small probability** that a GW detection is lensed (optical depth, $\tau \sim 10^{-3}$)
- Smallest GW **sky localisation** uncertainties are 10^8x larger than the angular scale of gravitational lensing (Einstein radius, $\theta_E \approx 0.5$-30arcsec)
- **Arrival time difference** between a pair of lensed images can significantly exceed GW detector coincident segment lengths and run lengths
- Candidate lensed BH-BH are degenerate with BH-BH that are not lensed in the **mass-distance** plane in low latency

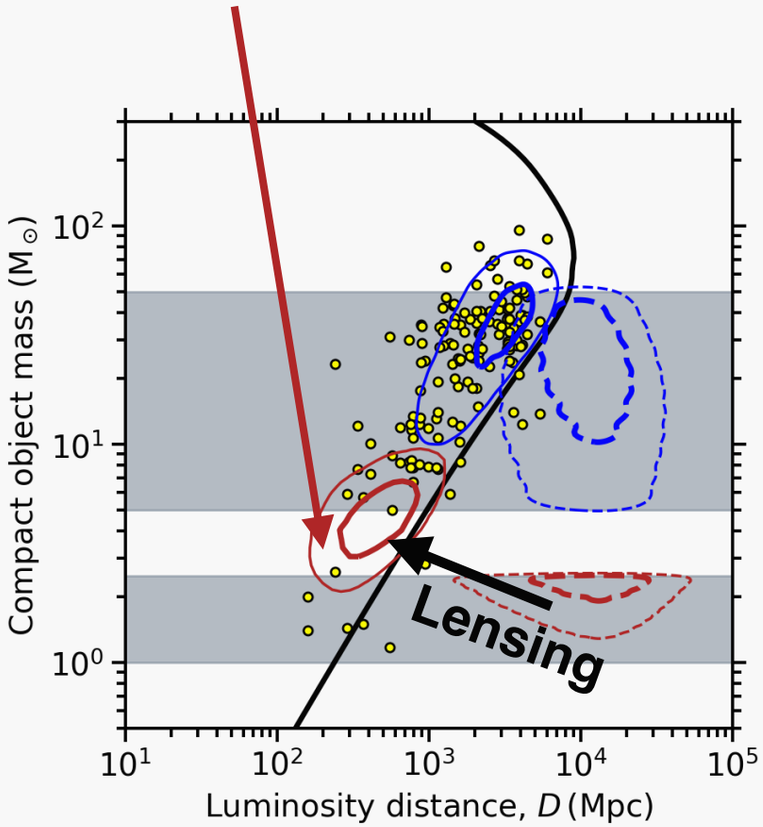
Solution:

- Concentrate on gravitationally **lensed NS-NS** mergers and their gravitationally **lensed kilonova** counterparts

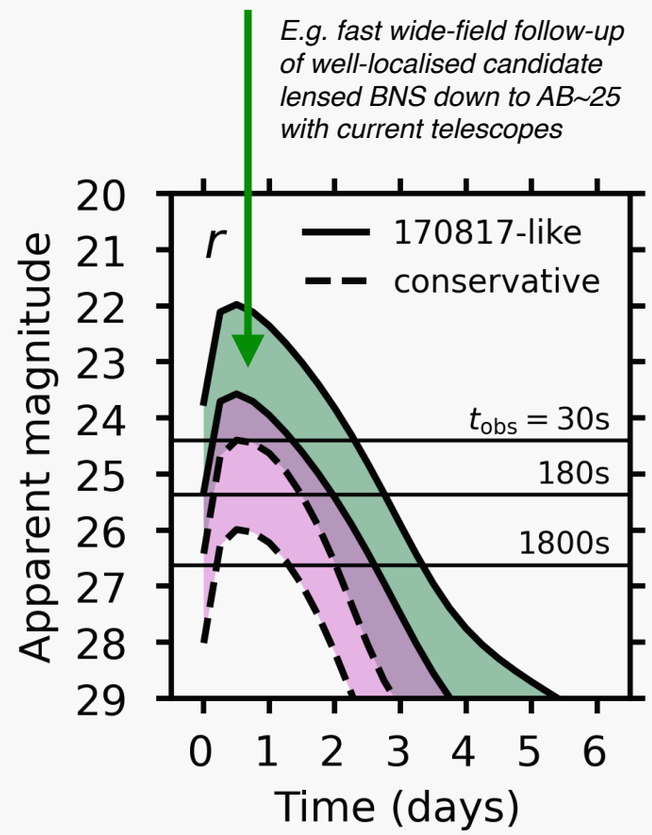
Ryczanowski D., et al., arXiv:2204.12984: building the watchlist of lenses for Rubin/LSST; danr@star.sr.bham.ac.uk
Bianconi M., et al., arXiv:2204.12978: optical follow-up of candidate lensed BNS in O3; mbianconi@star.sr.bham.ac.uk
Smith G. P., et al., arXiv:2204.12977: predictions for lensed BBH, BNS, kilonovae; gps@star.sr.bham.ac.uk
Nicholl M., et al., 2021, MNRAS, 505, 3016: forward model for kilonova lightcurves; mnicholl@star.sr.bham.ac.uk
Robertson A., et al., 2020, MNRAS, 495, 3727: what does strong gravitational lensing?; andrew.a.robertson@jpl.nasa.gov

Towards robust discovery of lensed GWs

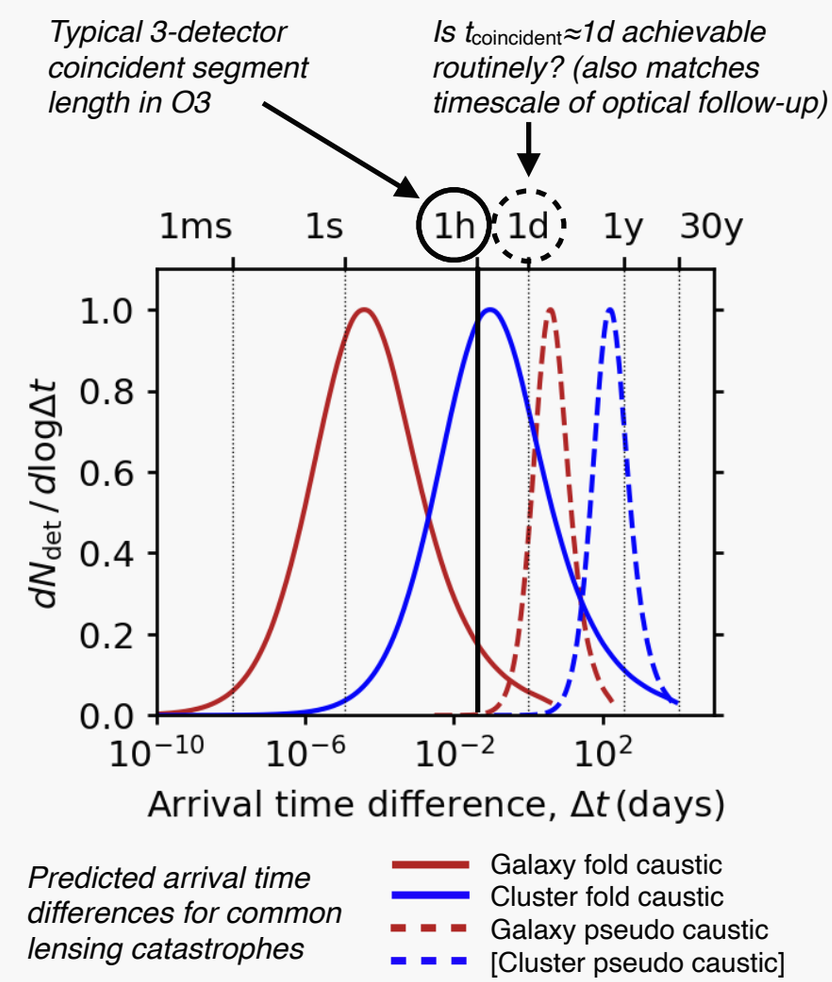
Detectable lensed NS-NS live in the mass gap in low latency



Lensed kilonovae are detectable in O4 (and O5)



Longer coincident segment lengths match Δt better



Requests for O4:

- Continue including p_{gap} in low latency alerts: flags objects of interest to us (and others!)
- Prioritise long multi-detector coincident segments: achieves better match with Δt for lensed BNS

Ryczanowski D., et al., arXiv:2204.12984: building the watchlist of lenses for Rubin/LSST; danr@star.sr.bham.ac.uk
Bianconi M., et al., arXiv:2204.12978: optical follow-up of candidate lensed BNS (p_{gap}>0.9) in O3; mbianconi@star.sr.bham.ac.uk
Smith G. P., et al., arXiv:2204.12977: predictions for lensed BBH, BNS, kilonovae with LVK and Rubin/LSST; gps@star.sr.bham.ac.uk
Nicholl M., et al., 2021, MNRAS, 505, 3016: forward model for kilonova lightcurves; mnicholl@star.sr.bham.ac.uk
Robertson A., et al., 2020, MNRAS, 495, 3727: what does strong gravitational lensing?; andrew.a.robertson@jpl.nasa.gov