Kilonovae and short hard bursts

a.k.a: electromagnetic counterparts to gravitational waves

Igor Andreoni for the Multi-Messenger Astronomy working group

Electromagnetic counterparts to gravitational waves

- Are neutron star mergers the dominant sites for heavy element nucleosynthesis?
- What extreme Physics can we learn?
- How can we use kilonovae for cosmology?
- What is the rate of binary neutron star and neutron star-black hole mergers?

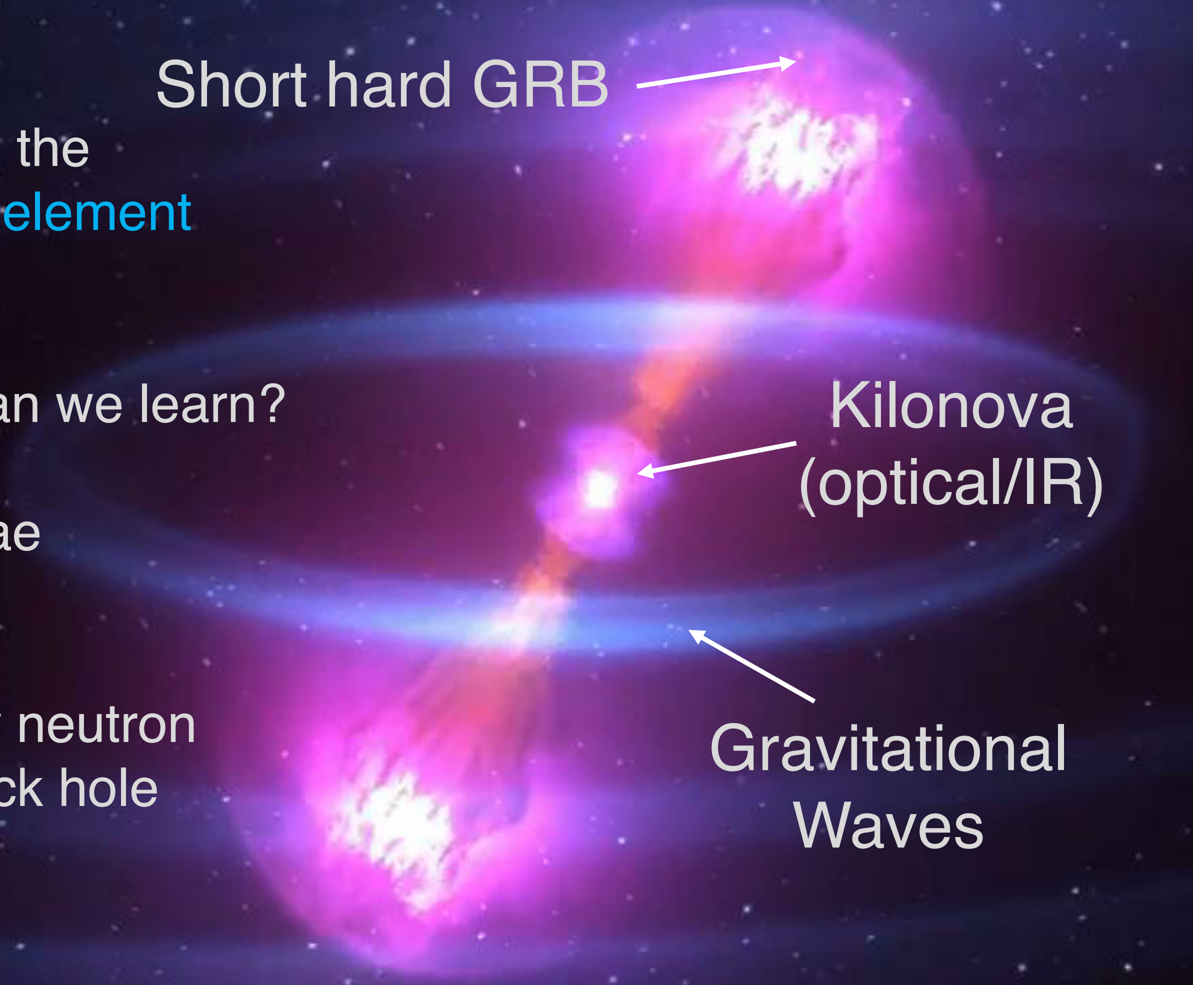
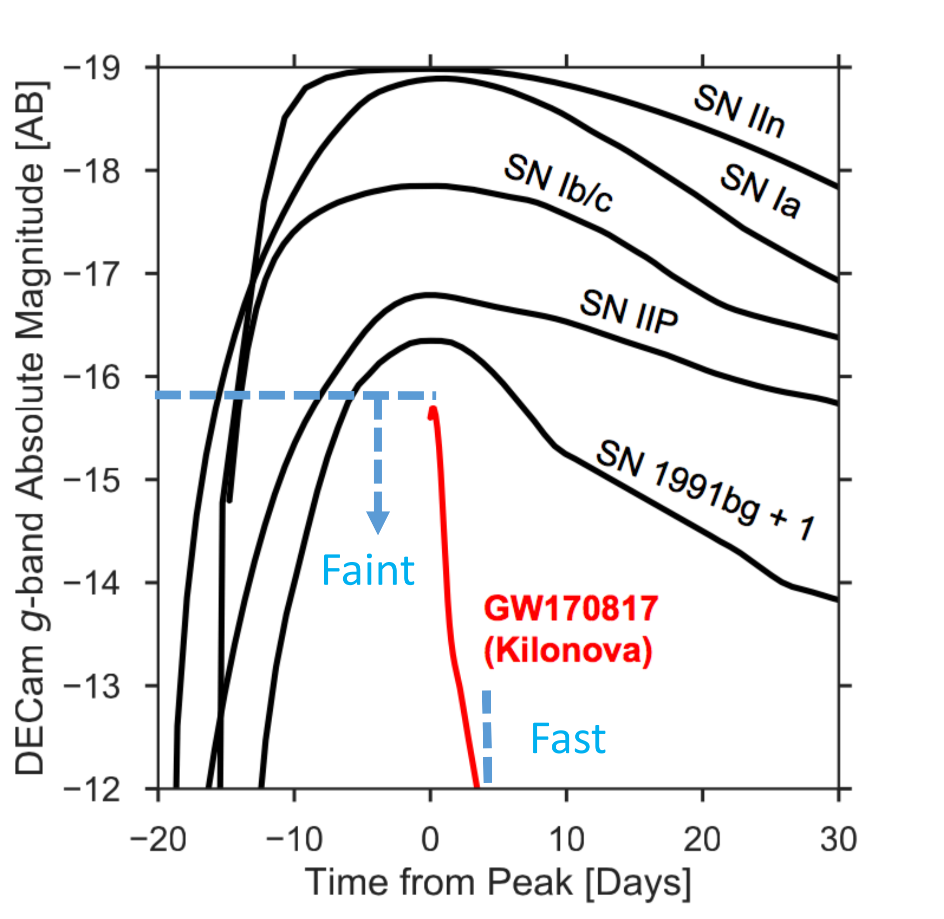


Image credit: NASA

Finding kilonovae is challenging!

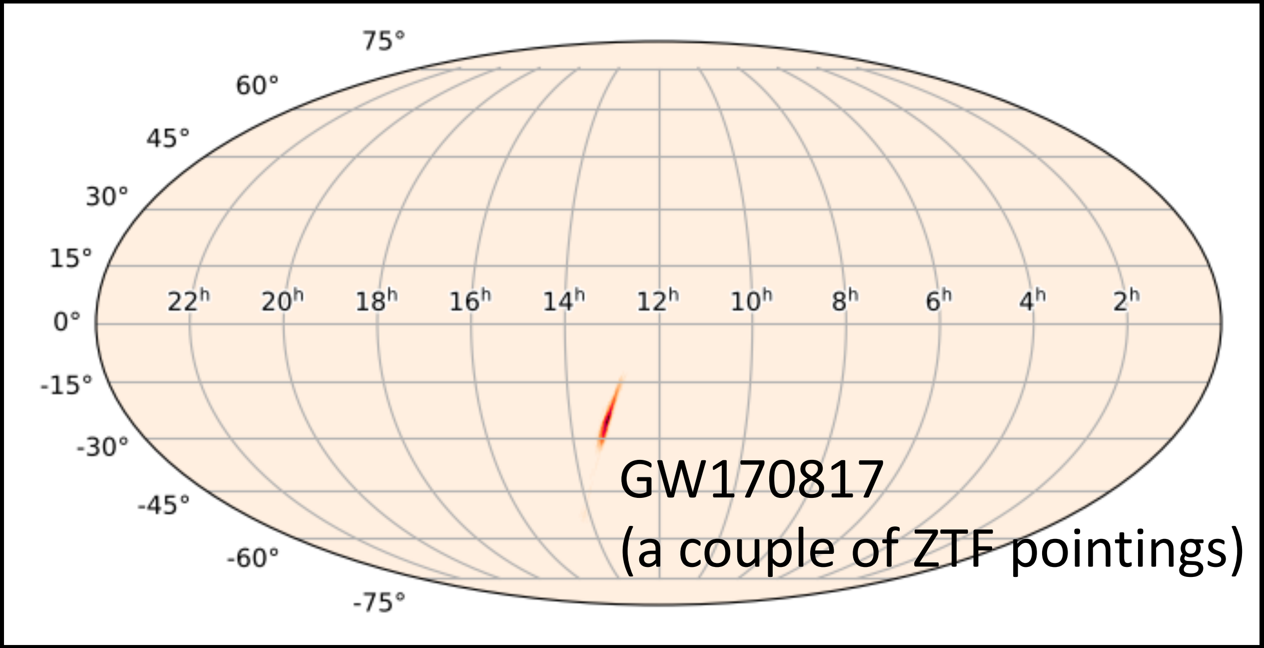
Kilonovae are rare, fast and faint transients compared to supernovae



modified from Andreoni+2018, LSST White Paper

Why do we need ZTF?

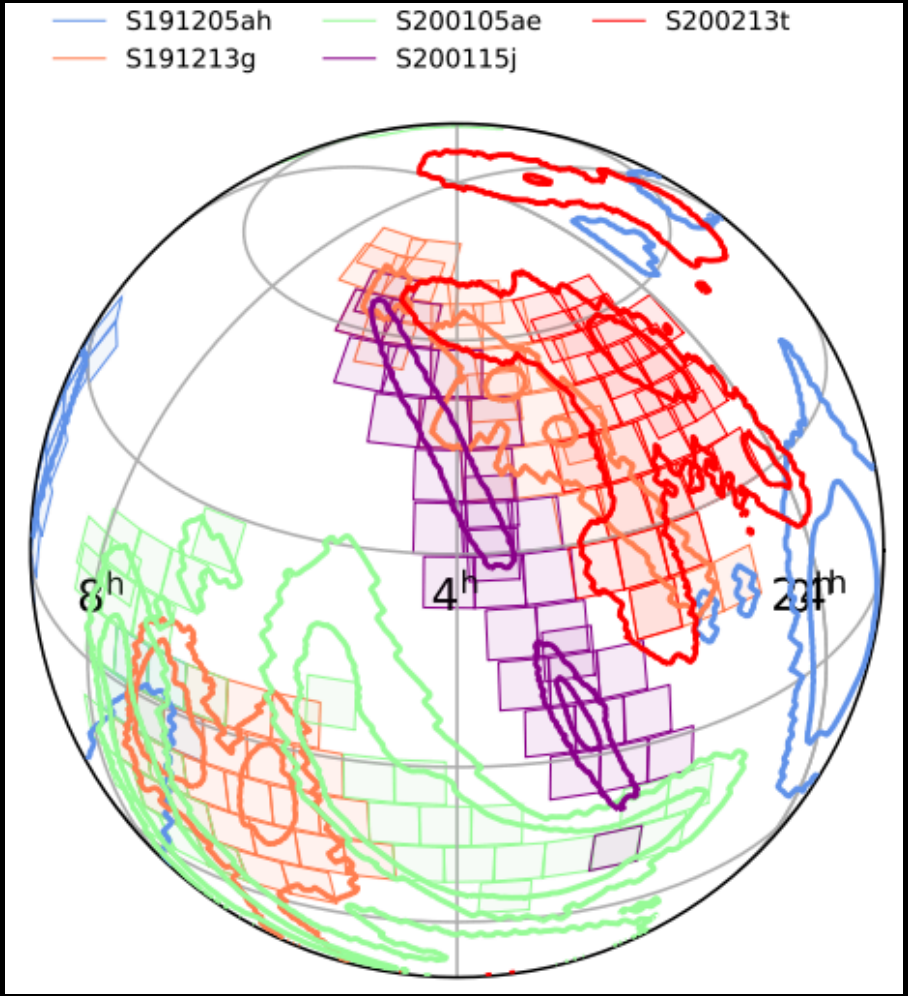
During the second LIGO-Virgo observing run (O2), the binary neutron star merger GW170817 was localized to 32 deg^2



During O3 (2019-2020), the median localization for neutron star mergers was 4,480 deg^2! …and the sources were more distant

Gravitational Wave follow-up during O3

We used ZTF to follow-up 15 GW triggers that included at least one neutron star



Kilonova luminosity function
Kasliwal et al., ApJ, in press

Second binary NS merger follow-up
Coughlin et al., ApJ Letters,
Vol 885, Issue 1, article id. L19, 13 pp.

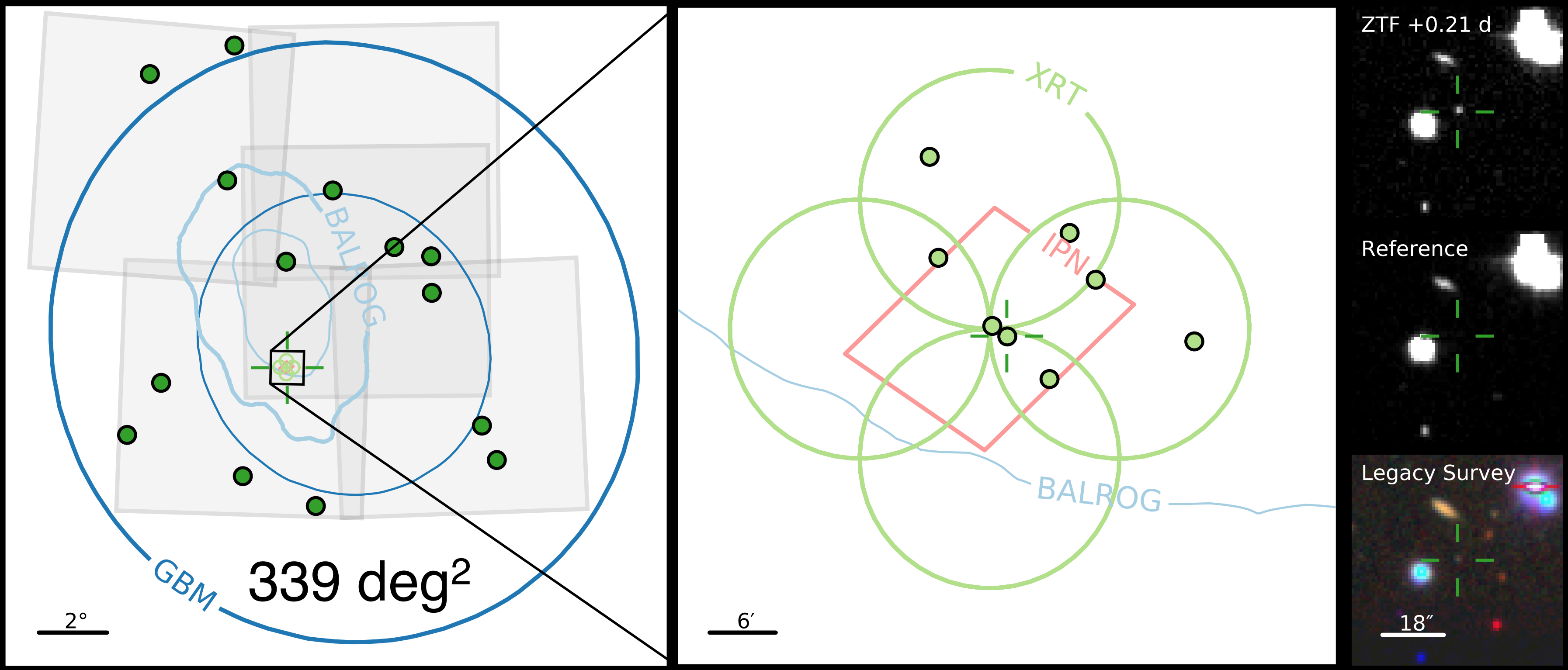
Constraints on NS-BH merger
Anand & Coughlin et al.,
Nature Astronomy, in press

Short, hard gamma-ray bursts (GRBs)

We used ZTF to follow-up 8 short GRBs found by the *Fermi* satellite

Ahumada et al., in prep.

Found one afterglow! Shortest GRB from collapsar ever found



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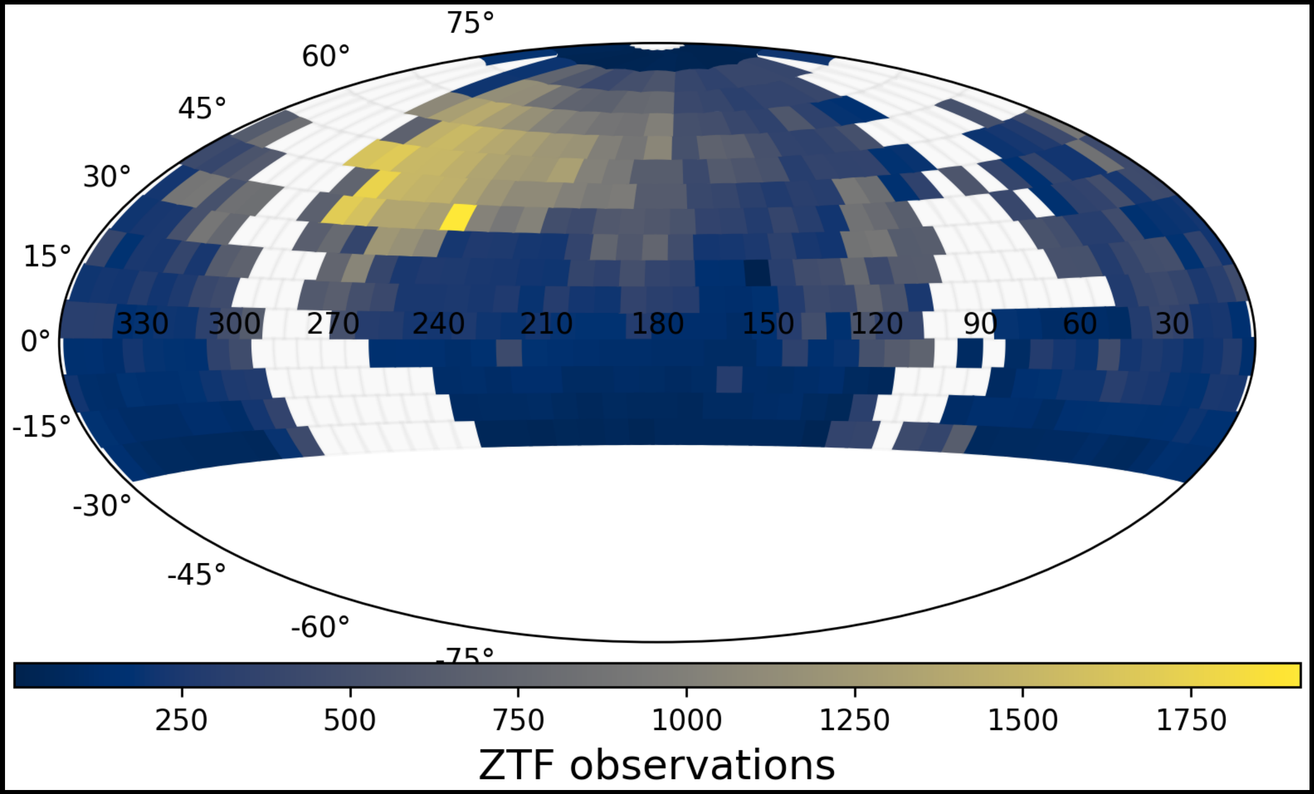
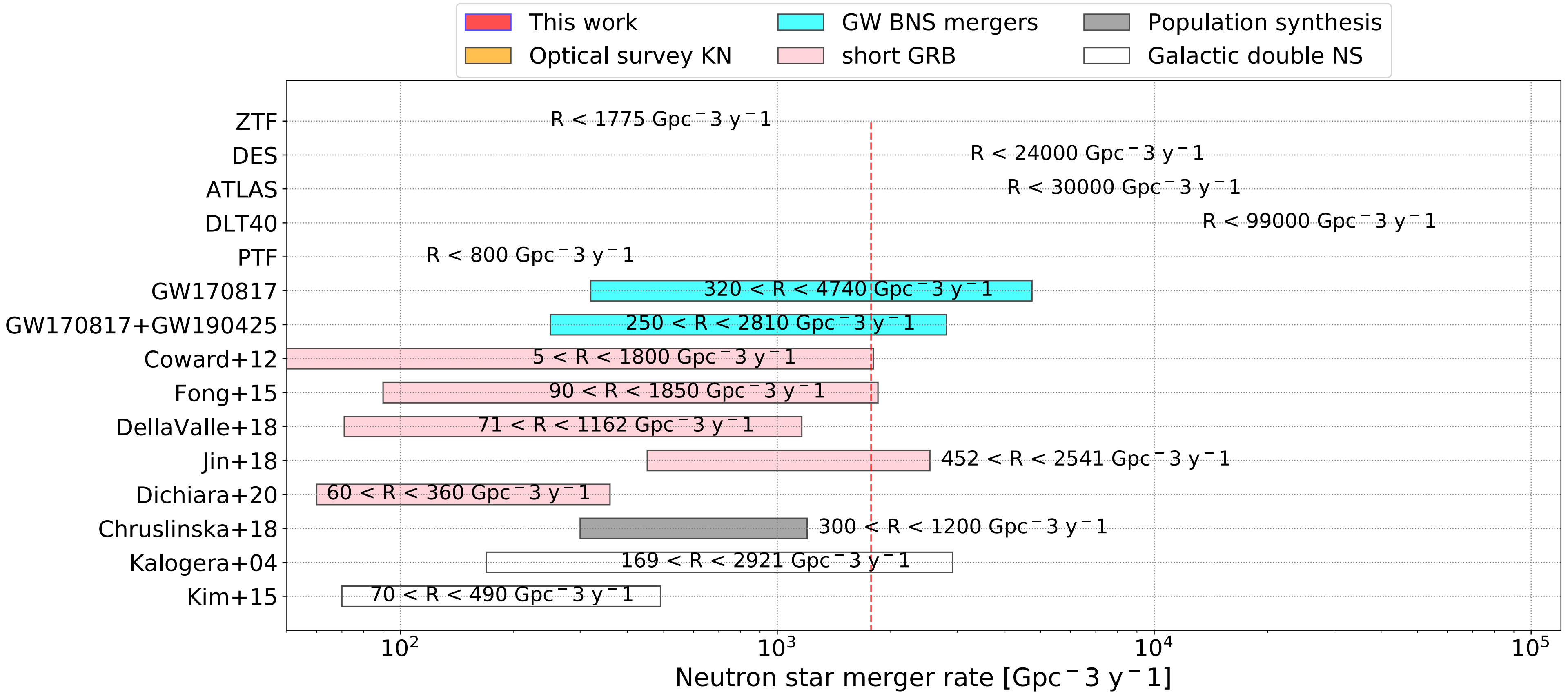


Challenge accepted:

We have searched for kilonovae in two years of ZTF survey data

Constraints on Kilonova and neutron star merger rates



ZTF constrained the rate of GW170817-like kilonovae to be $R<1775$ Gpc^{-3} y^{-1}

Andreoni et al., ApJ, in press, arXiv:2008.00008

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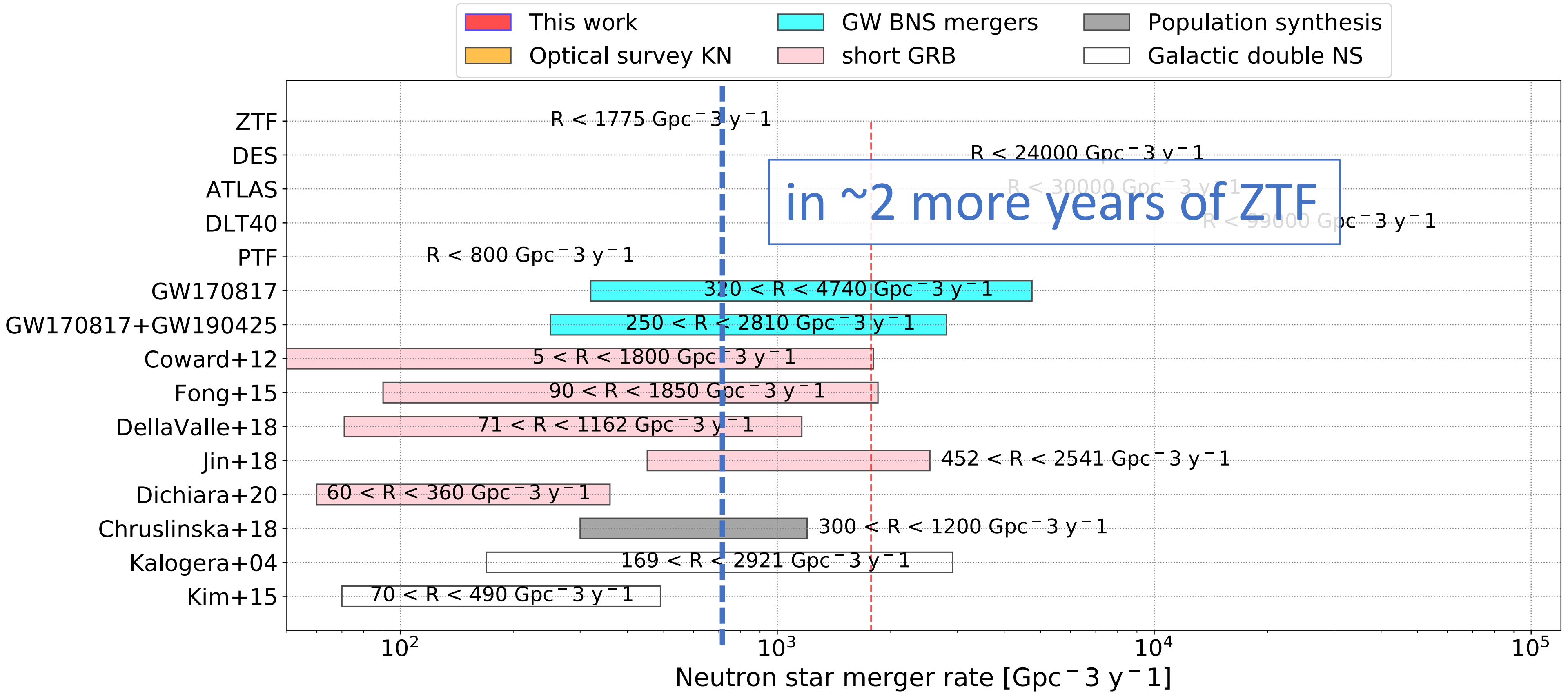

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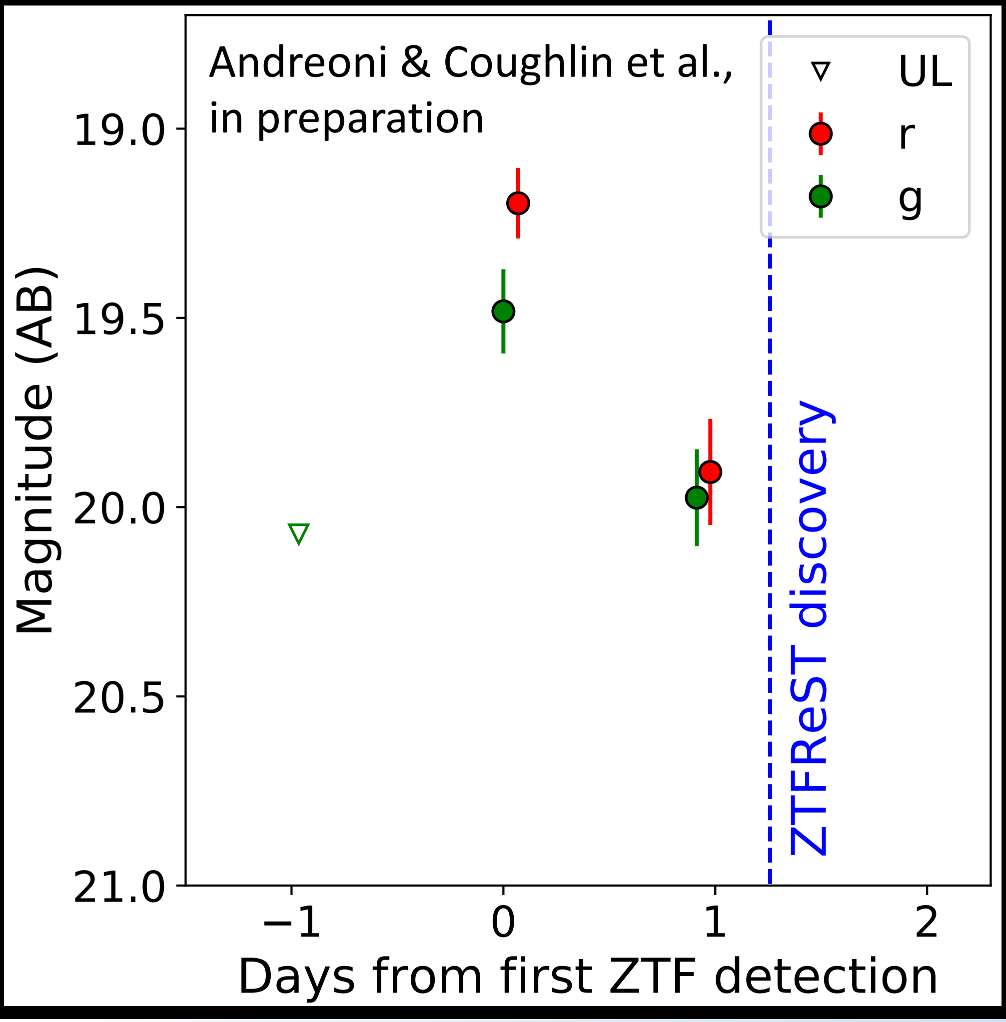
Looking ahead: ZTFReST

ZTF Realtime Searching and Triggering



growth-astro/ztfrest

Near real-time implementation of the search methods used in Andreoni+20d;
automatic triggering of follow-up photometry with LCO telescopes

For results from a different fast transient search pipeline see, for example, Ho+2020

Summary

ZTF has proven to be an excellent facility to search for rare, elusive counterparts to multi-messenger sources

Wide-field follow-up with ZTF played a key role in O3, allowing us to do science even without a positive kilonova detection

Short GRB follow up is on-going and it has yielded the shortest GRB with associated supernova to date

Systematic searches in ZTF data constrained the kilonova rate to be $R<1775$ Gpc^{-3} y^{-1}, which can tell us something about the neutron star merger rate

Our knowledge will greatly improve thanks to triggered and un-triggered searches in ZTF Phase II

Thank you for your attention!