



Caltech

Un-triggered kilonova searches with ZTF to measure the neutron star merger rate

Igor Andreoni, Tomàs Ahumada, Mouza Al Mualla, Shreya Anand, Ana Sagués-Carracedo, Michael Coughlin, Mansi Kasliwal, Erik Kool, and friends

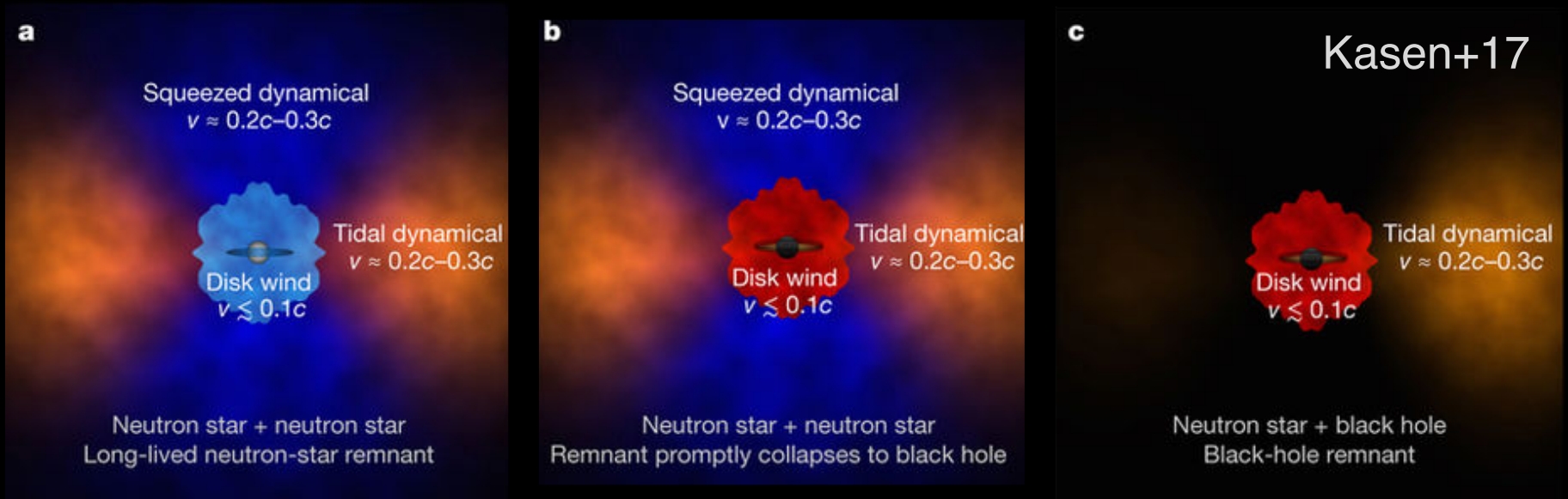


ZTF Collaboration Meeting

October 21st 2020

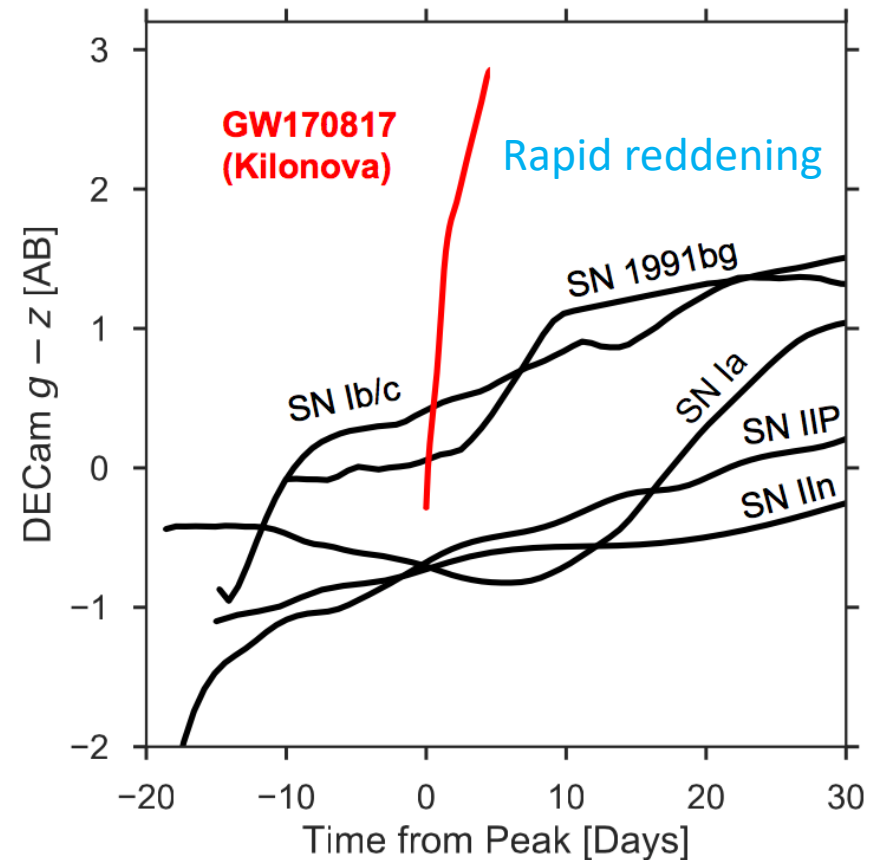
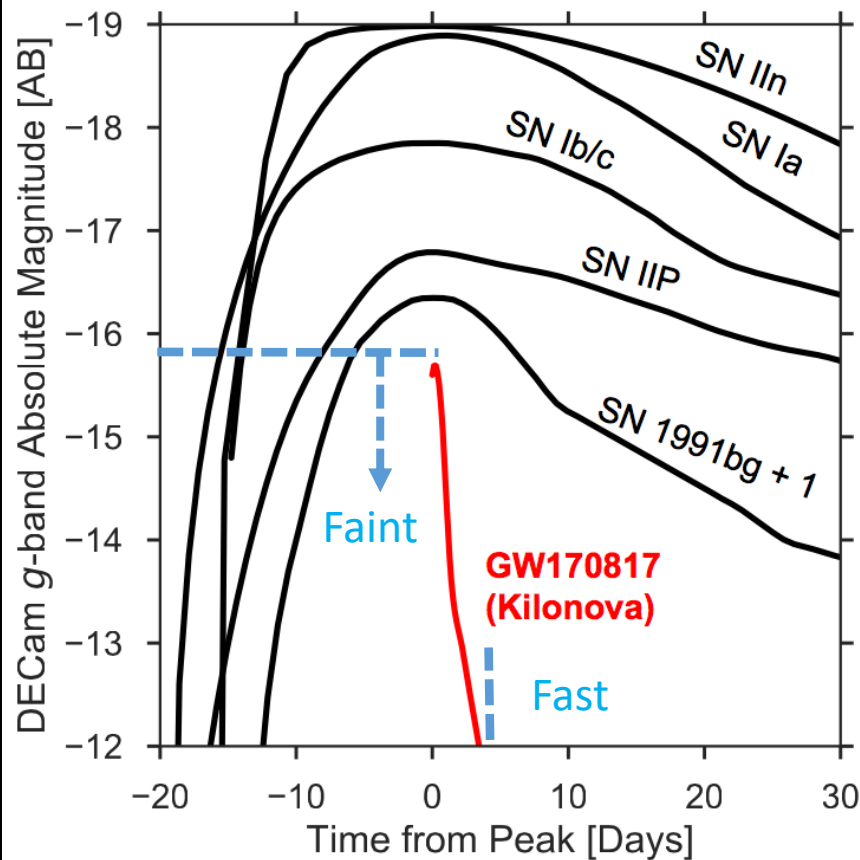
Kilonovae

Optical/IR signatures of neutron star mergers



- Important for cosmology (help pin-point GW "standard sirens"). Can they also be "standardizable" candles?
- Are neutron star mergers dominant sites for heavy element nucleosynthesis?
- What is the kilonova luminosity function?
- What is the rate of binary neutron star and neutron star-black hole mergers

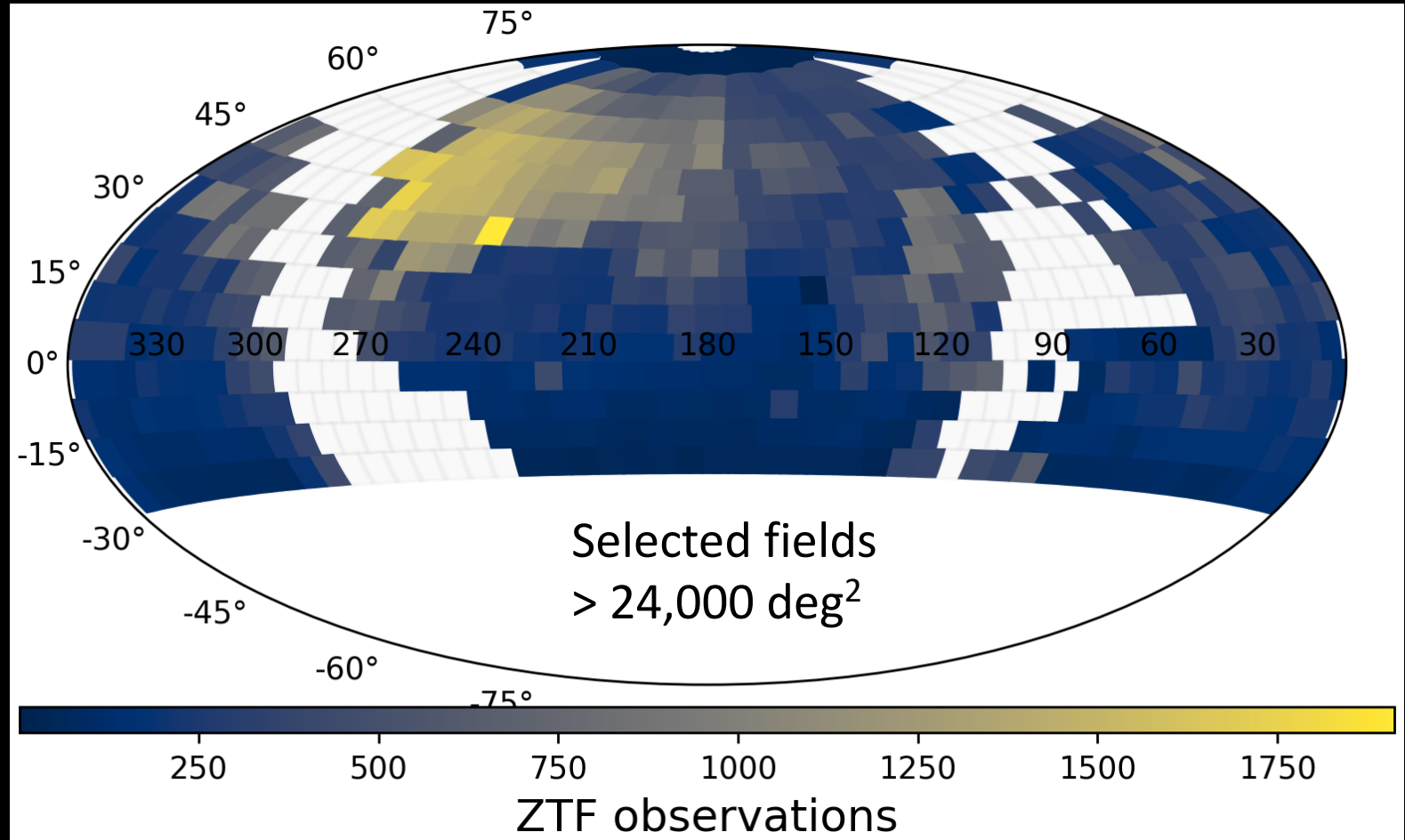
Kilonovae appear to be fast and rapidly reddening transients



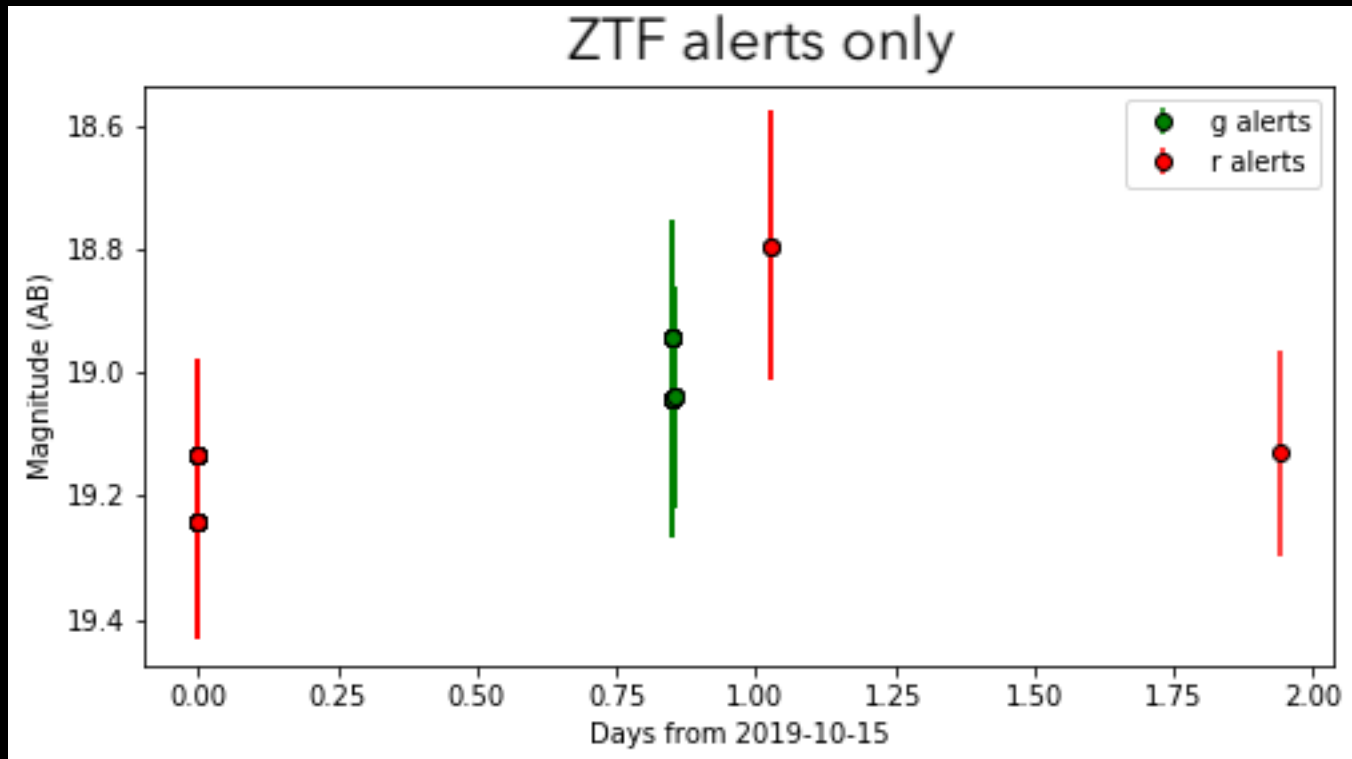
Plot by D. Goldstein

modified from Andreoni+2018, LSST White Paper

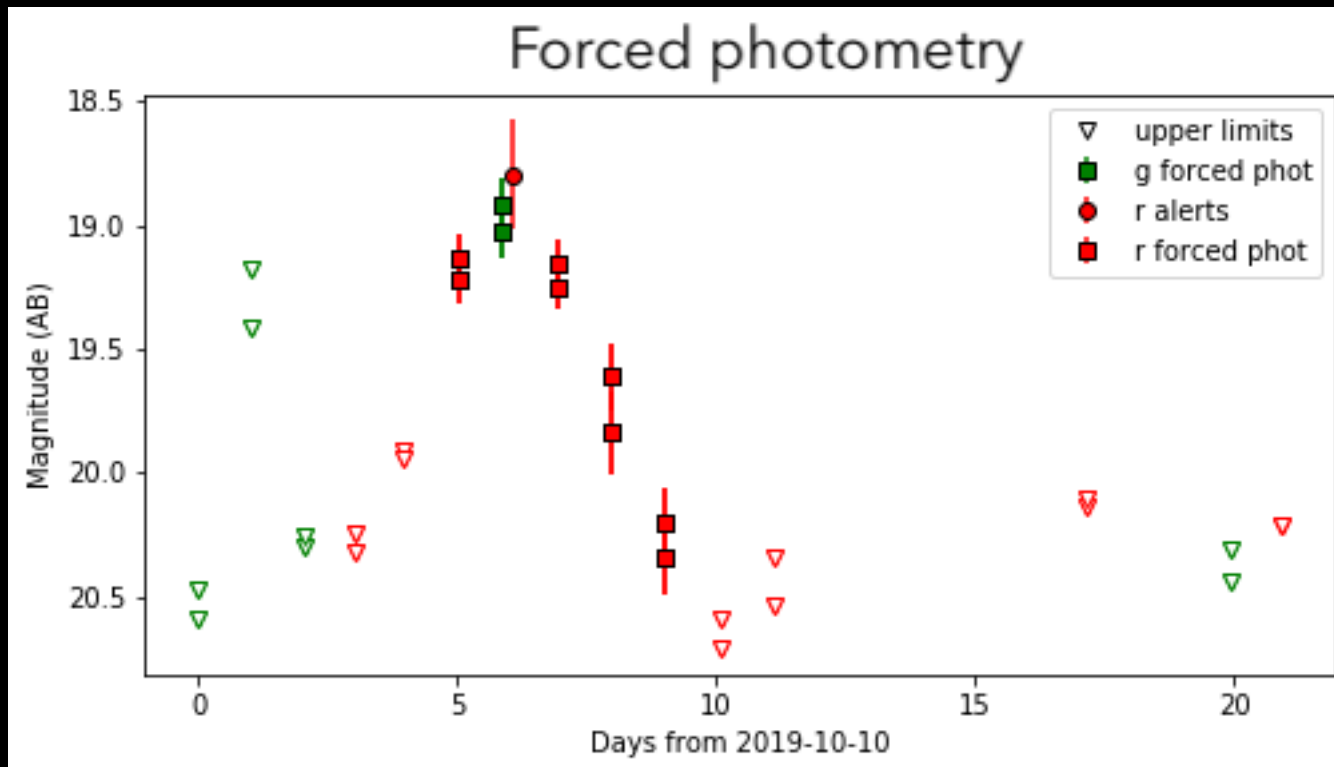
Zwicky Transient Facility Survey



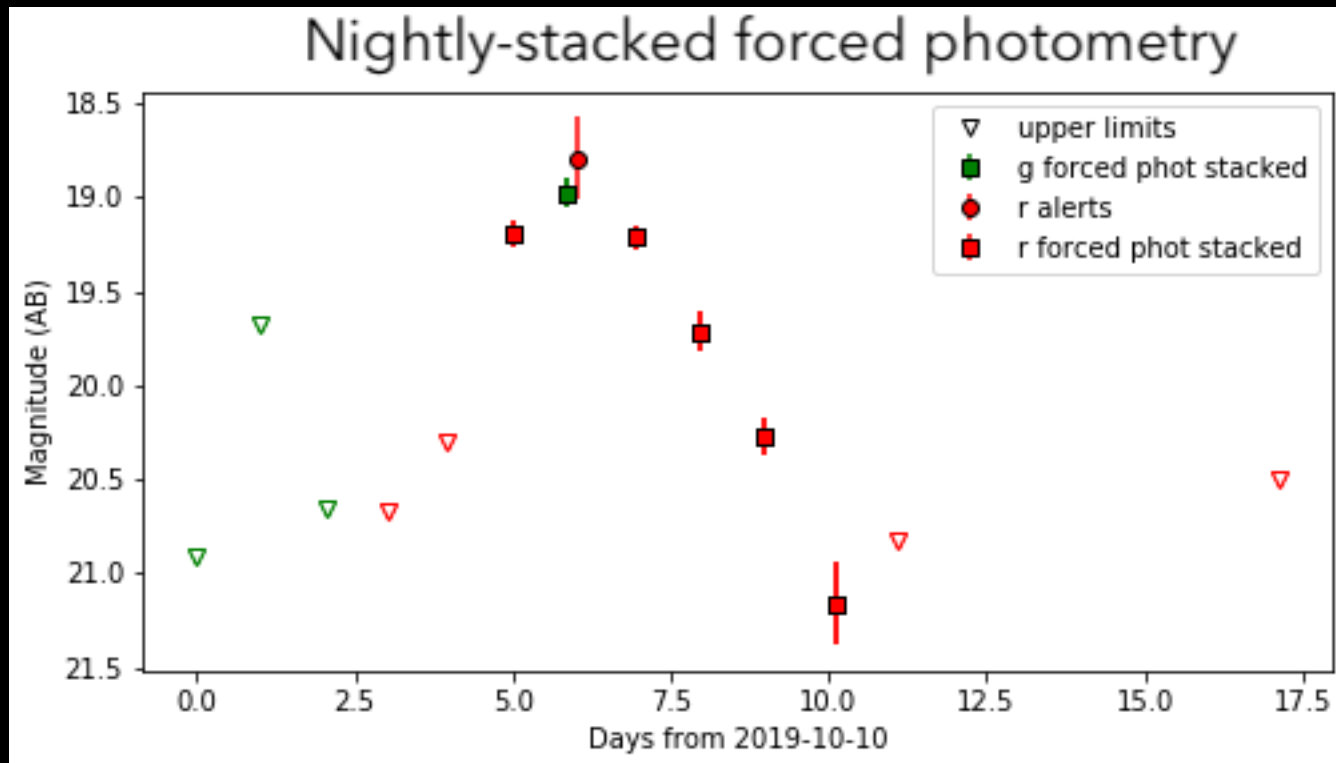
A transient with...alerts



The same transient with... forced photometry



The same transient with... stacked forced photometry



Results

11,202 candidates from both galaxy-targeted and all-sky searches

24 candidates pass our strict selection criteria

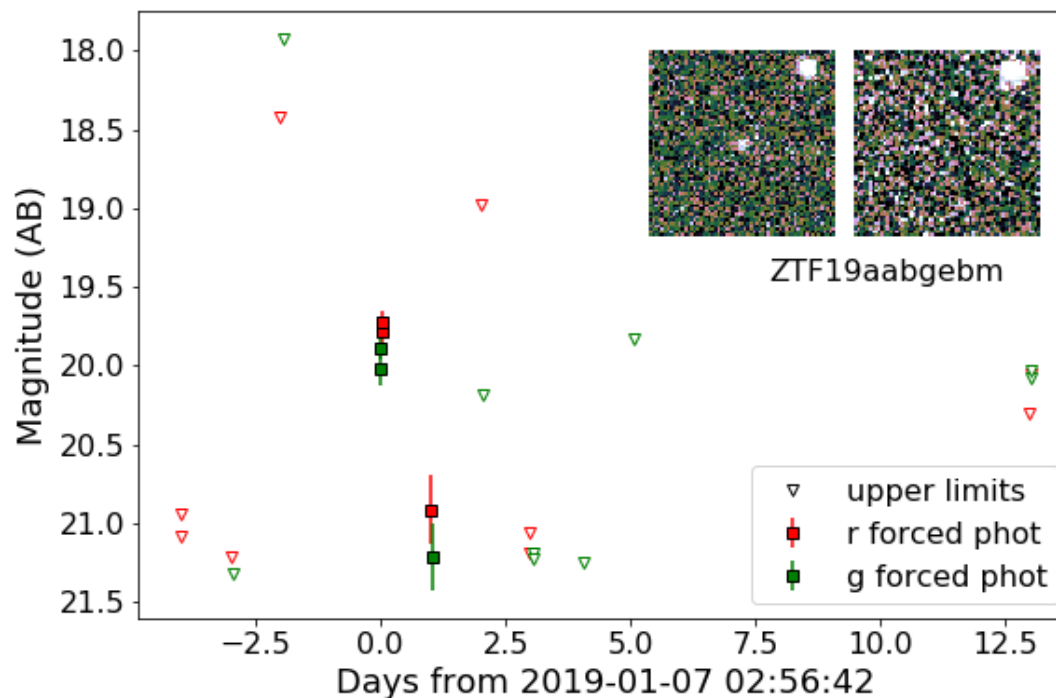
Mostly **Galactic** foreground sources (cataclysmic variables)

A couple of special ones...



Erik Kool
(OKC)

Serendipitous discovery of a GRB afterglow at $z=1.86$



Tomàs
Ahumada
(UMD)

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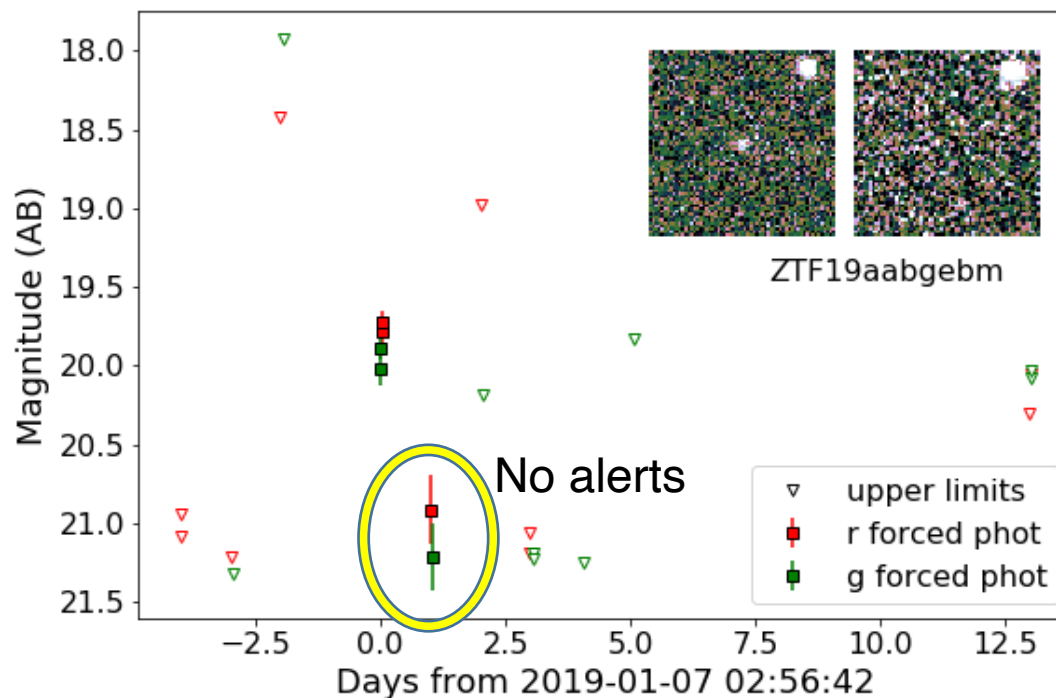
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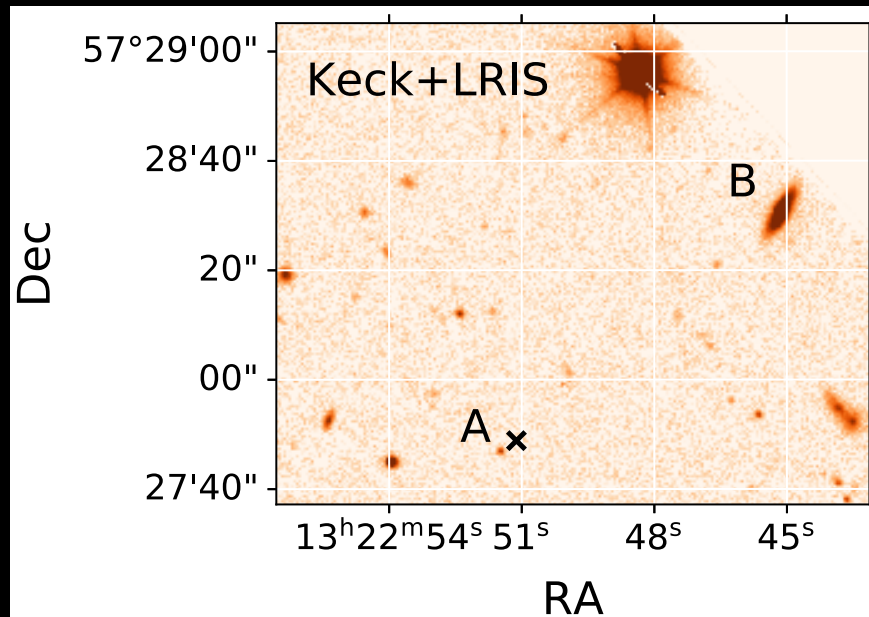
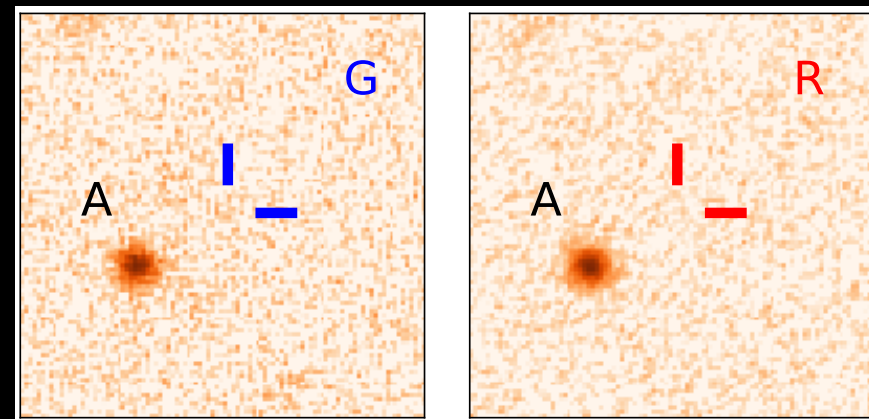
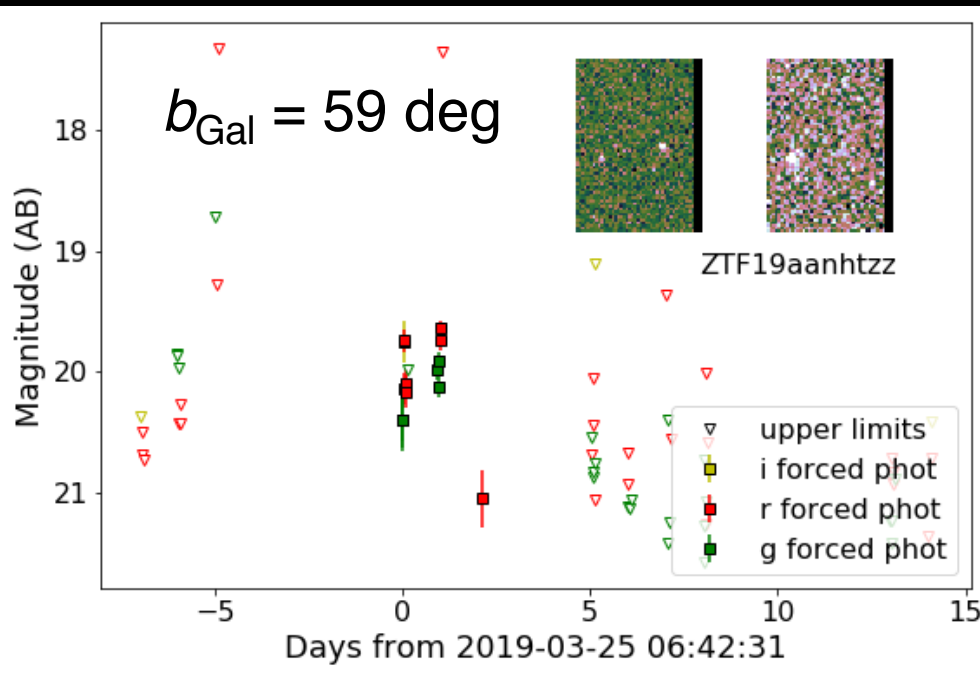
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Serendipitous discovery of a GRB afterglow at $z=1.86$



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(UMD)

Results



A cosmological afterglow?

Forced photometry is available, link in the paper

Results from 23 months of ZTF searches

11,202 candidates from both galaxy-targeted and all-sky searches

24 candidates pass our strict selection criteria

Mostly Galactic foreground sources (cataclysmic variables)

A couple of special ones

0 viable kilonovae

Can we calculate the kilonova rate given a non-detection?

~YES!

We can constrain the kilonova rate given
a number of **models** and assumptions
on the **luminosity function**



(see Shreya Anand's talk, Kasliwal+2020)

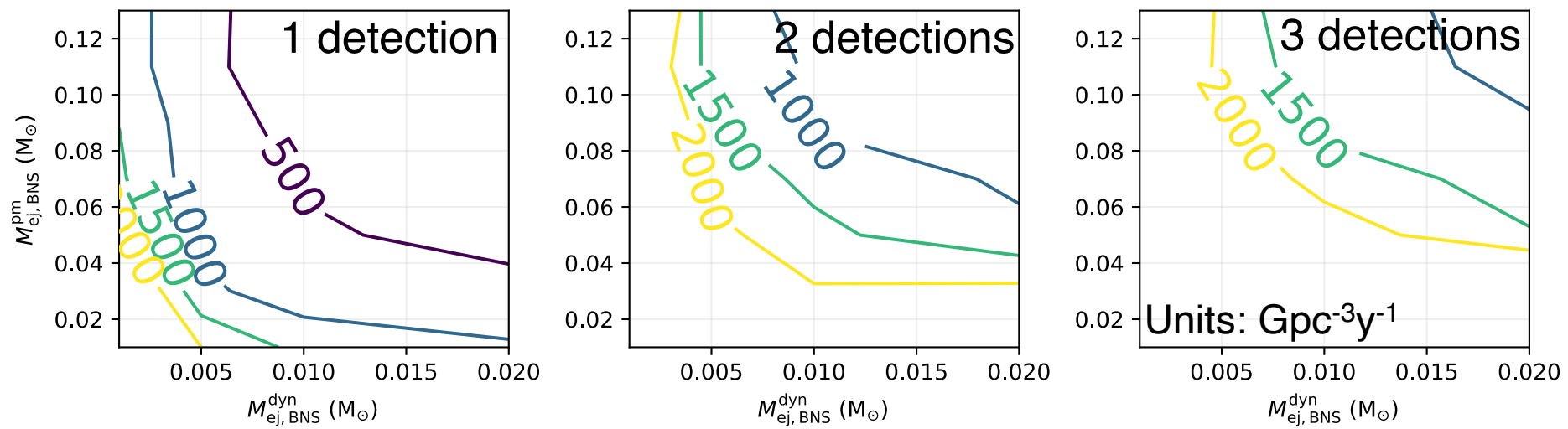


Kilonova rates



We injected synthetic kilonova light curves and calculated the rates based on the simulated transient recovery

Grids of rates for several parameter spaces and models including Top hat model; Linear decay model; Radiative transfer simulations



Models by M. Bulla, simulations by A. Sagués-Carracedo (OKC)



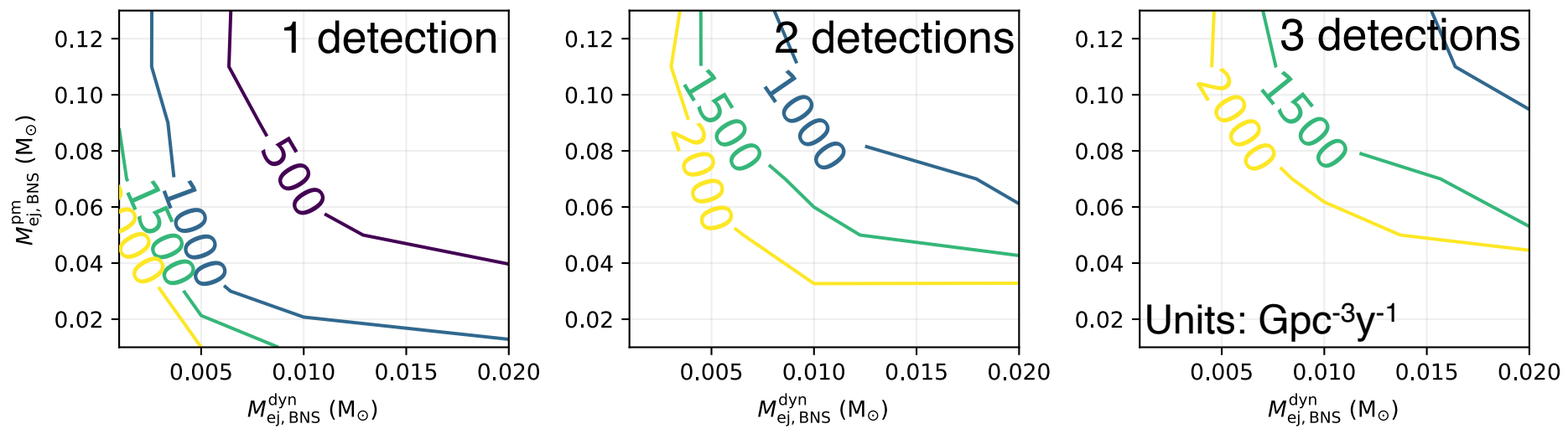
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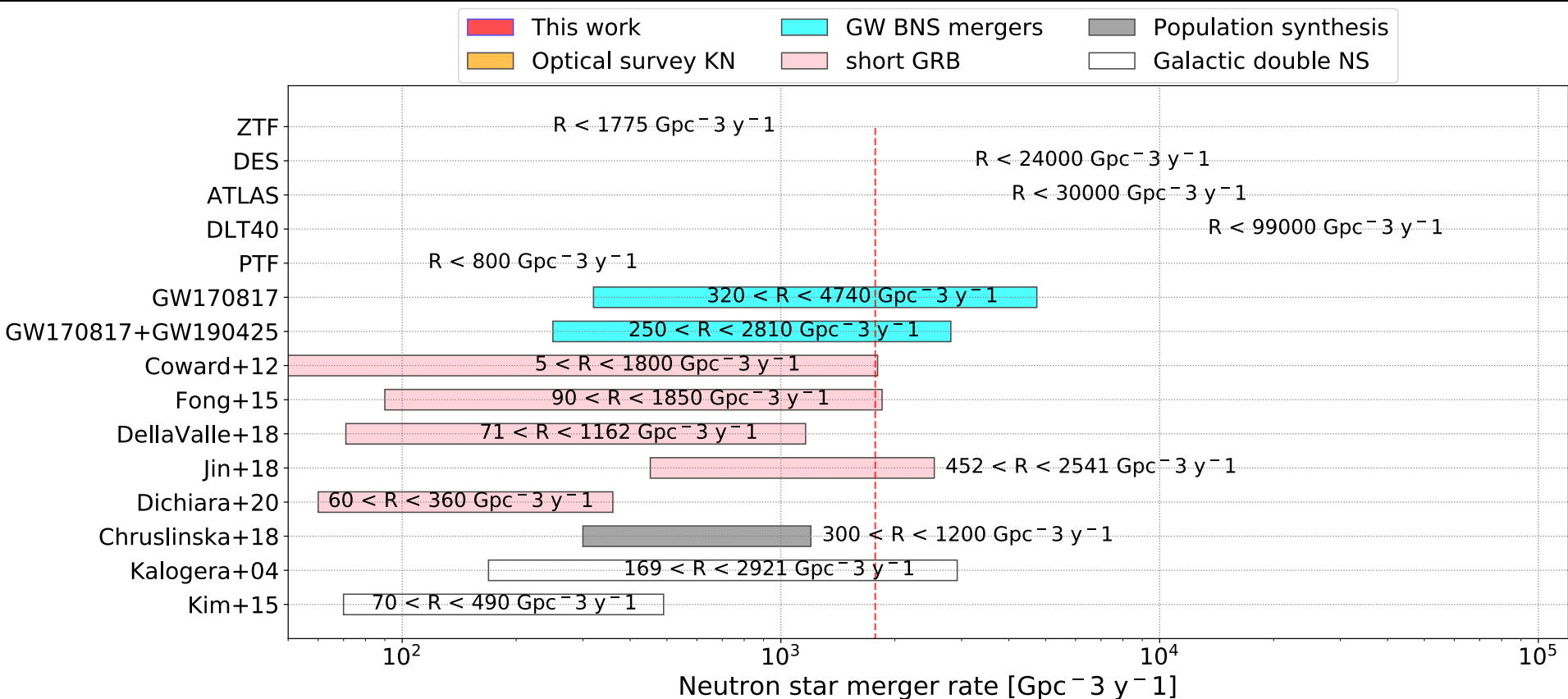
Try out your model!

Grids of rates for several parameter spaces and models including Top hat model; Linear decay model; Radiative transfer simulations



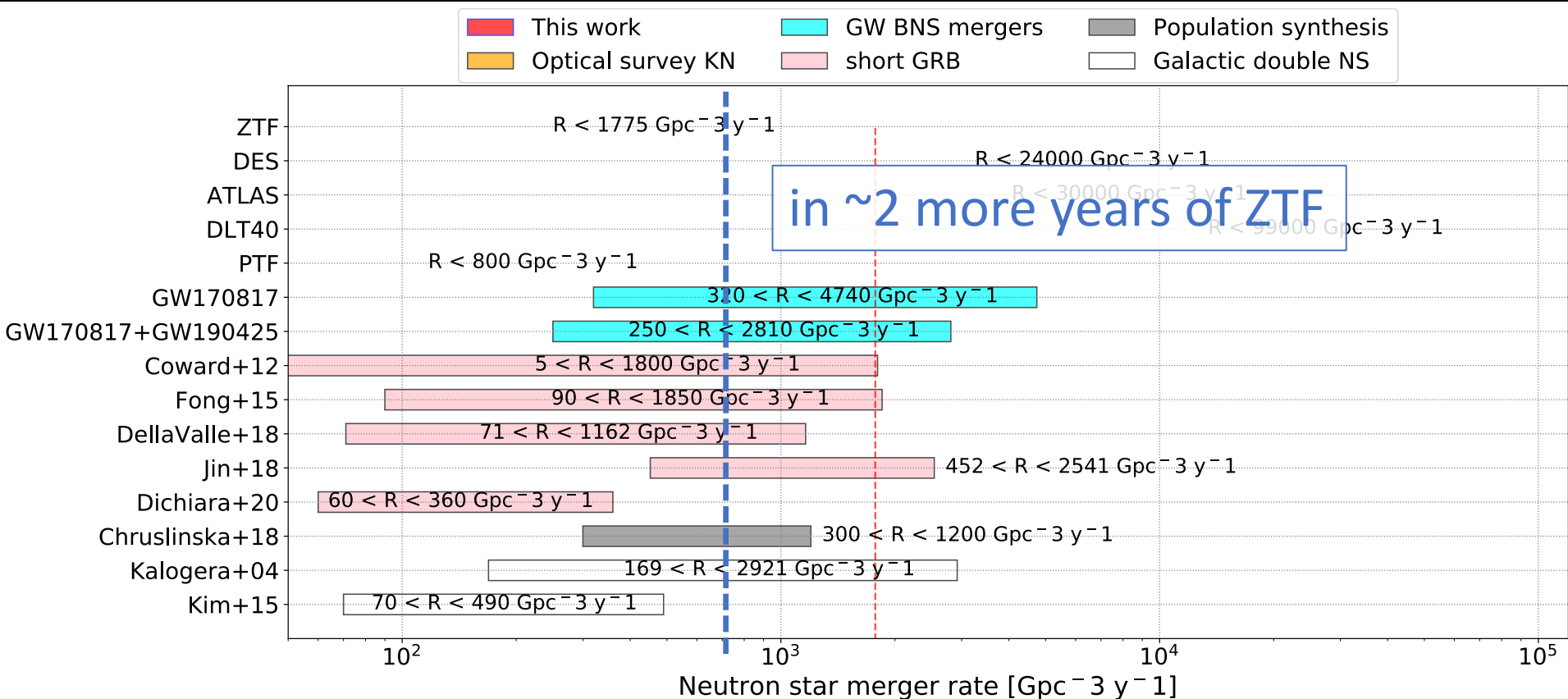
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Kilonova and neutron star merger rates



Andreoni et al., accepted for publication in ApJ, [arXiv:2008.00008](https://arxiv.org/abs/2008.00008)

Kilonova and neutron star merger rates



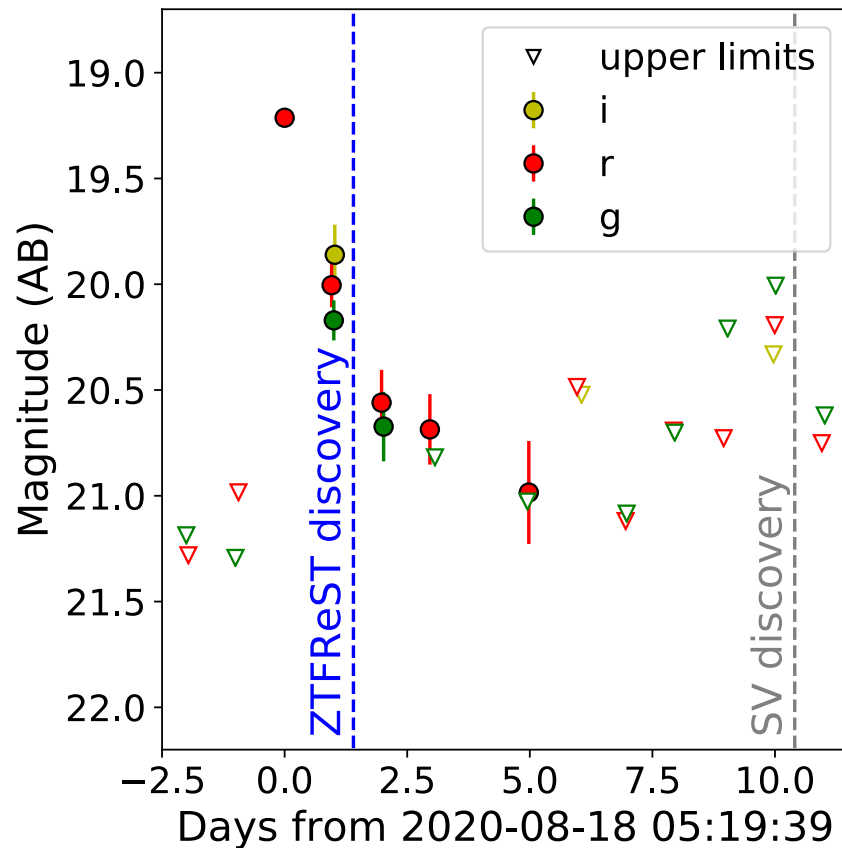
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ZTFReST

ZTF Realtime Searching and Triggering



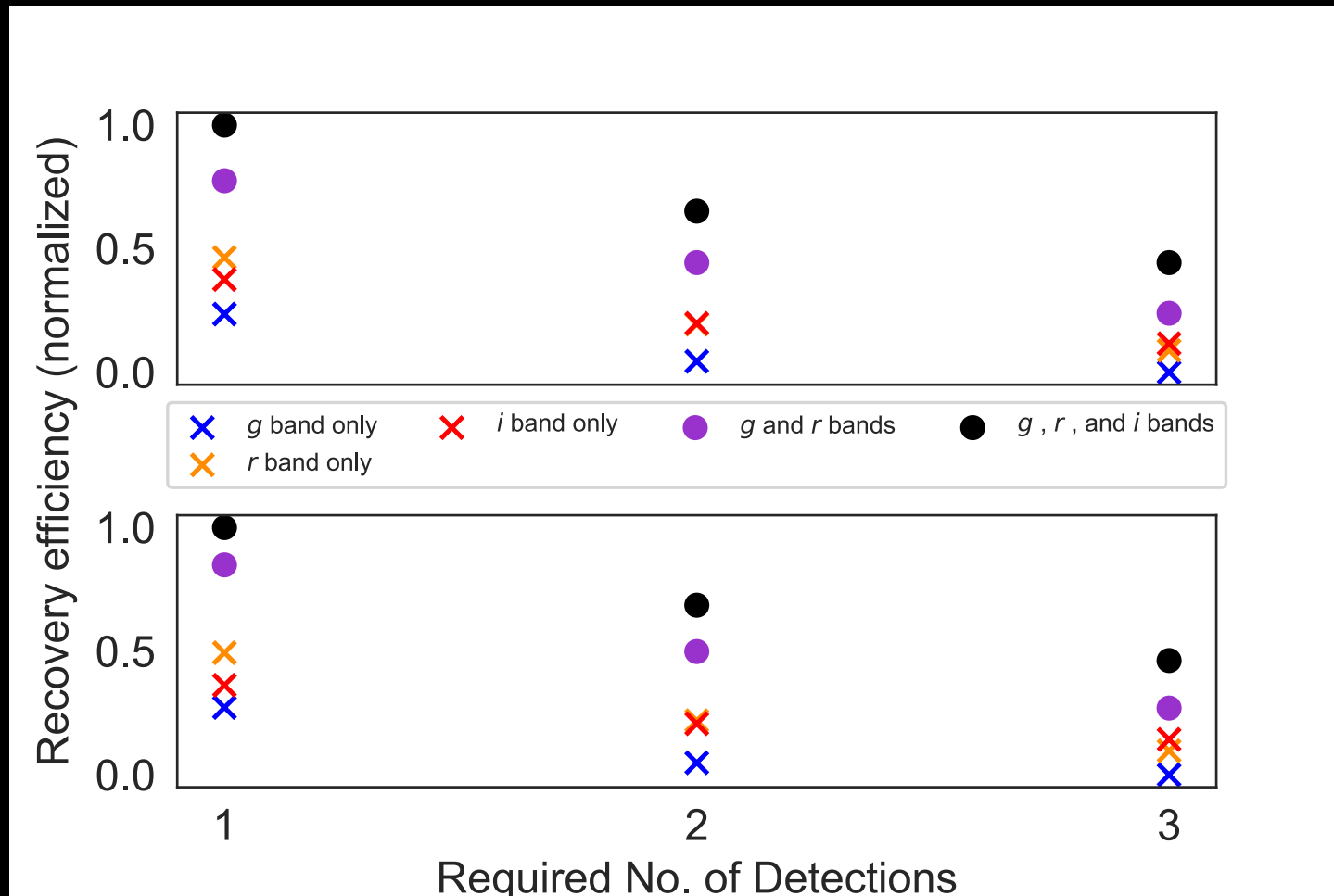
Andreoni & Coughlin et al., in prep



[growth-astro/ztfrest](https://github.com/growth-astro/ztfrest)

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

How can we find more kilonovae serendipitously in ZTF?



Almualla et al., in preparation

Take-away

Many **open questions** remain about kilonovae and neutron star mergers

Systematic searches in ZTF constrained the rate of GW170817-like kilonovae to be **$R < 1775 \text{ Gpc}^{-3} \text{ yr}^{-1}$** , which can tell us something about the **neutron star merger rate**

With ZTFReST and other new programs, the ZTF collaboration is better placed than ever to discover kilonovae **in real time**

Our knowledge will greatly improve thanks to both **triggered** and **un-triggered** searches in the next couple of years.

Thank you for your attention!