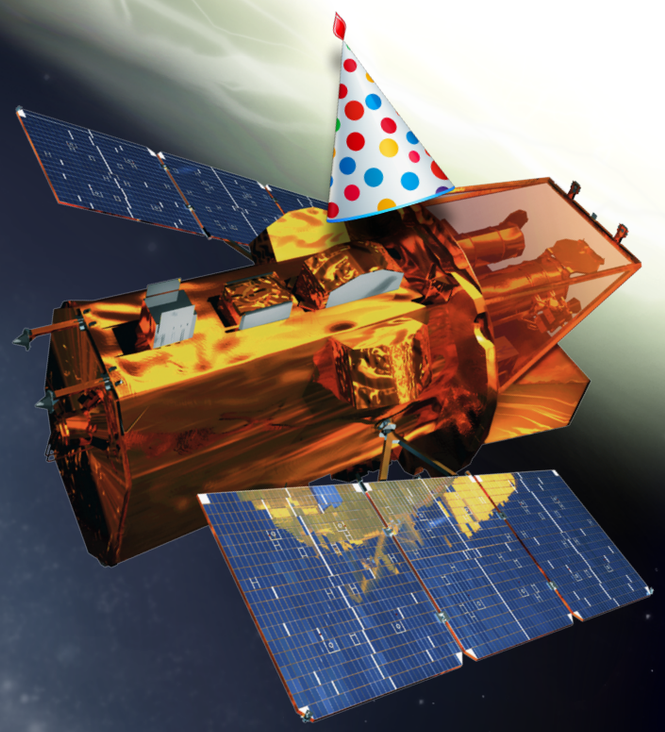


Image Credit: Aaron Geller, Northwestern

# THE DIVERSITY OF NS MERGER COUNTERPARTS REVEALED BY SWIFT


JILLIAN RASTINEJAD

Northwestern Presidential Fellow

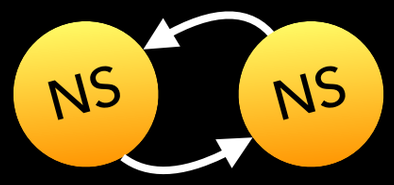
Northwestern | CIERA

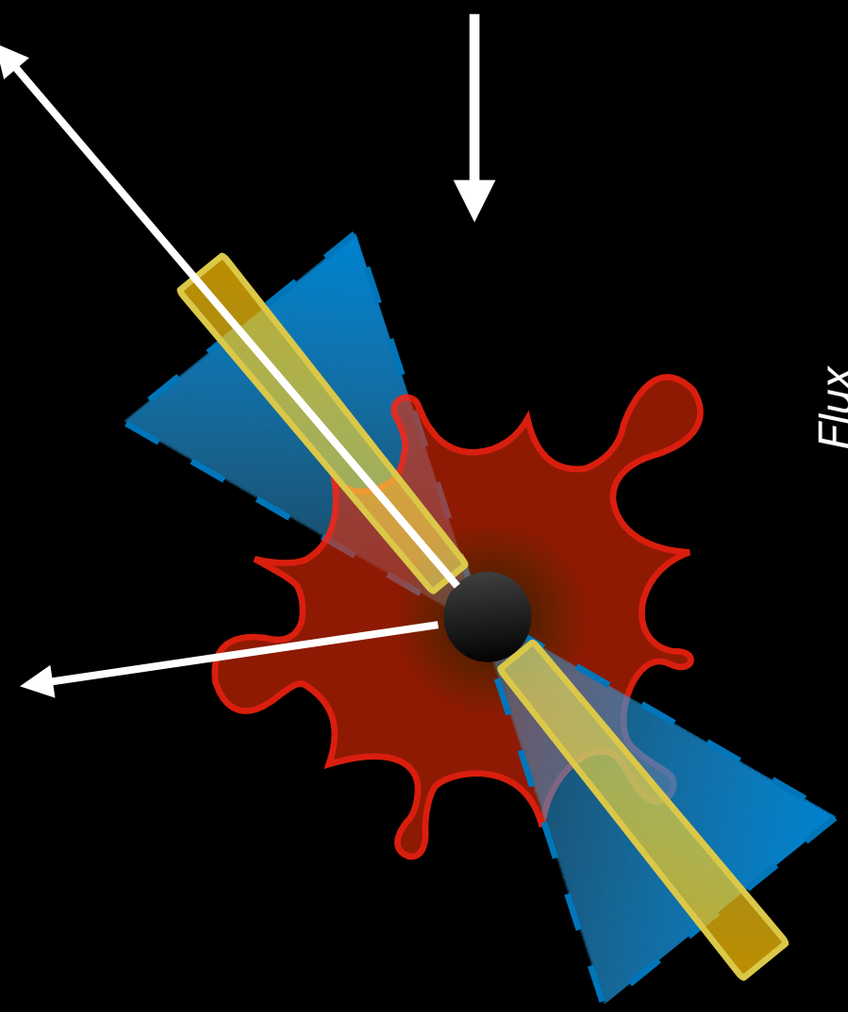
CENTER FOR INTERDISCIPLINARY EXPLORATION AND RESEARCH IN ASTROPHYSICS

# The EM Counterparts to NS Mergers

**Potential Counterpart**

**GRBs + on-axis afterglows**



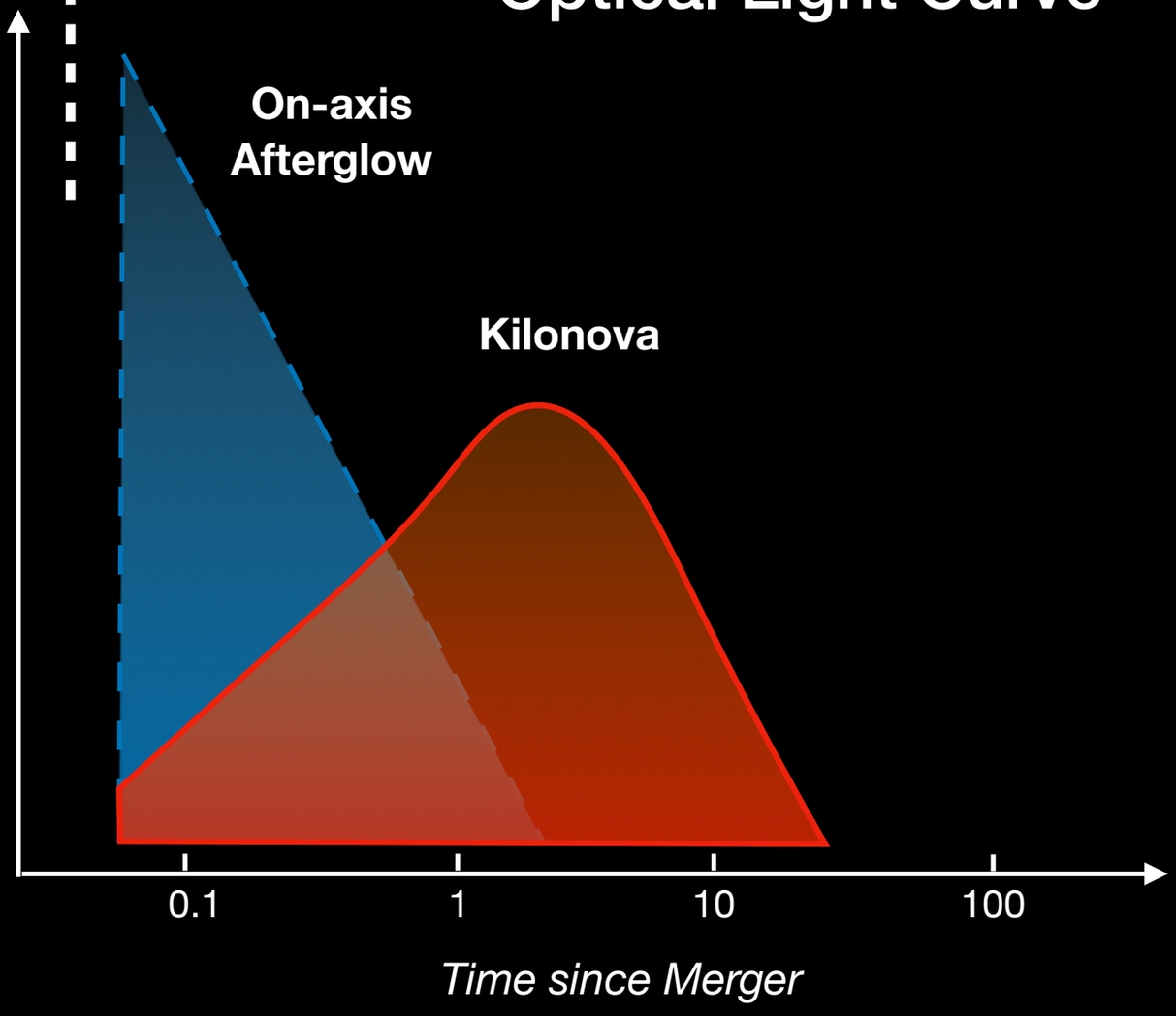
**Kilonova**

**GRB Detection**

## Optical Light Curve

**On-axis Afterglow**

**Kilonova**

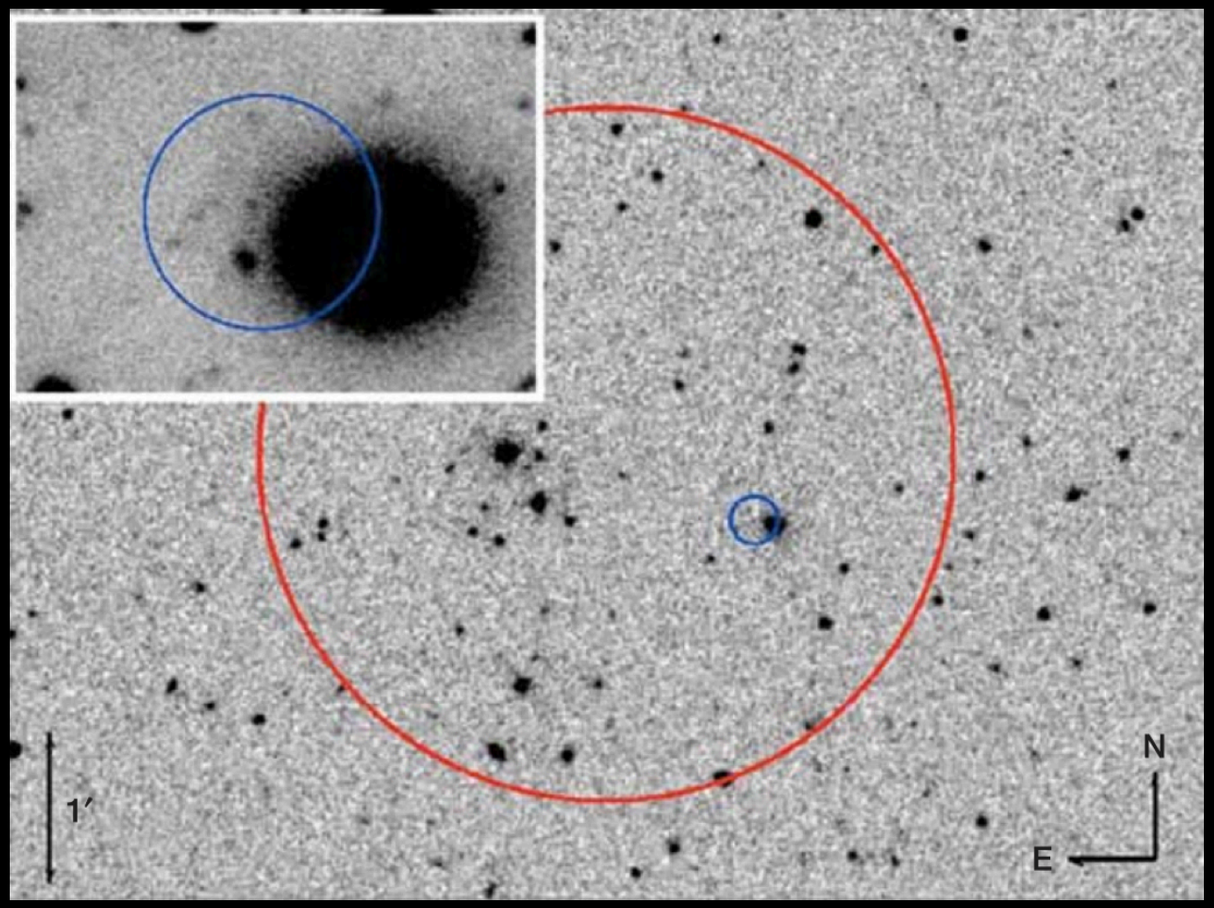


# Swift's Untouched Legacy in sGRB afterglows...

**sGRB 050509B:**

XRT associates sGRB to quiescent host

Allows deep limits on sGRB optical AG

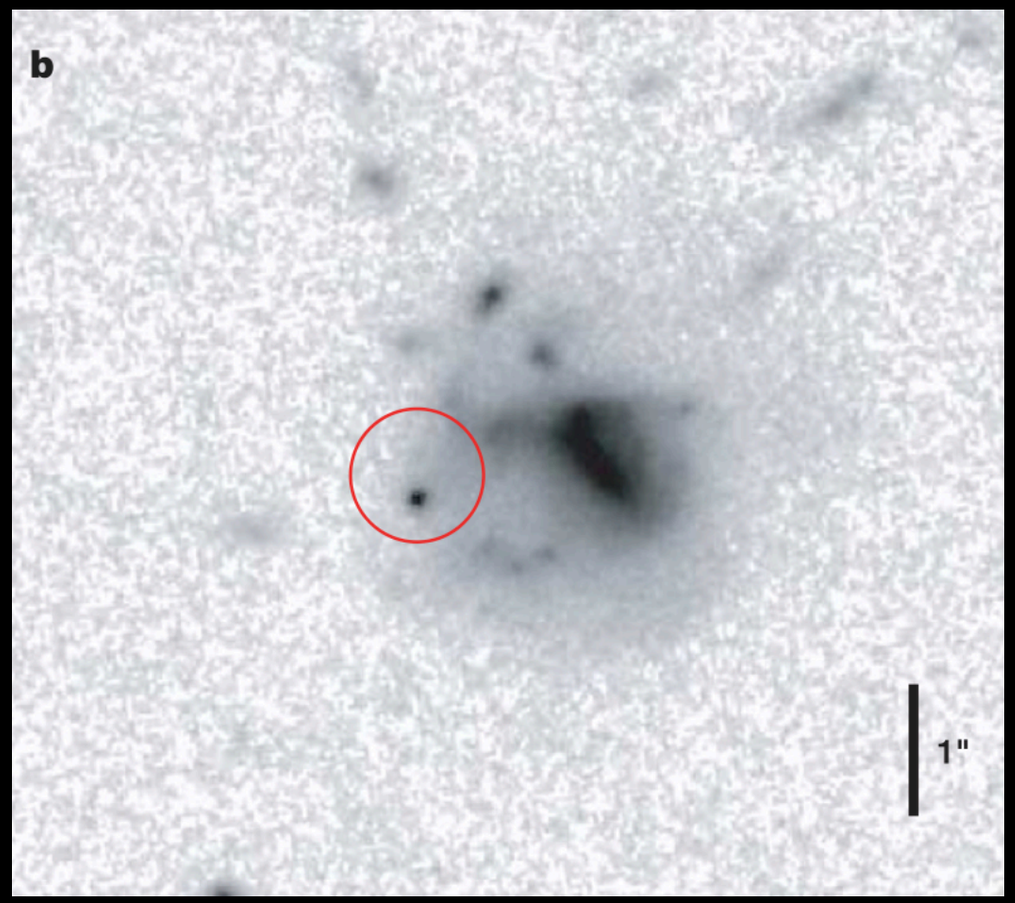



Gehrels+05, see also Bloom+06

**sGRB 050709:**

XRT confirms fading counterpart,

First optical sGRB afterglow

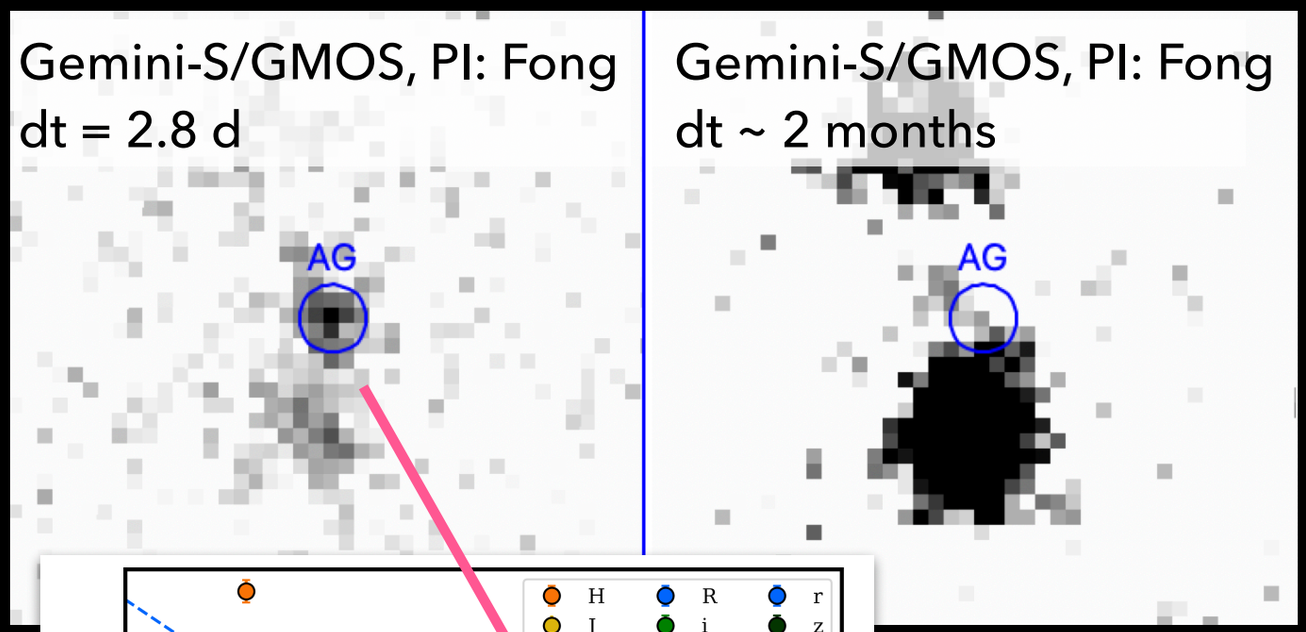


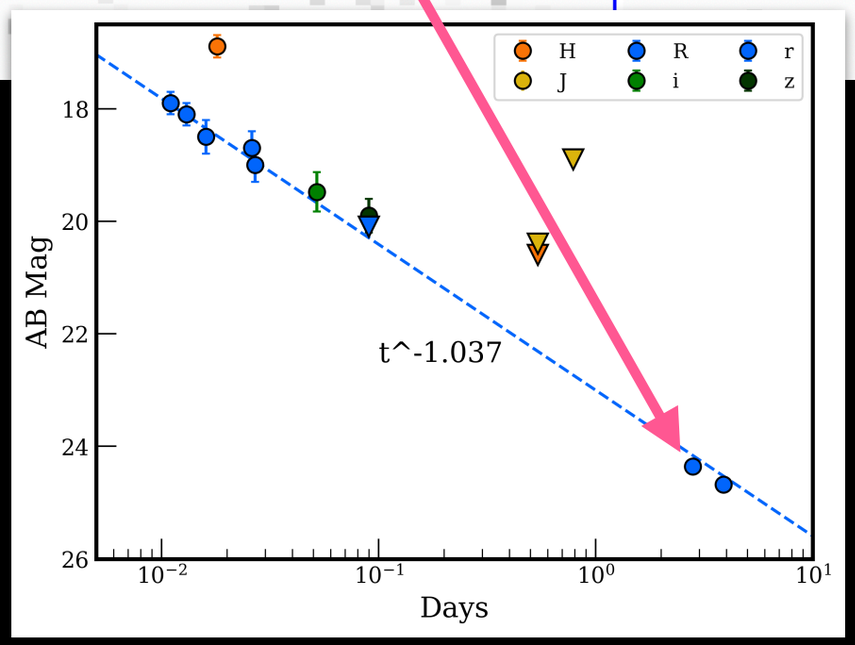

Fox+05, see also Hjorth+05

Enabled first constraints on jet energies, insight to host environments + redshift distribution, etc.

# Swift's Untouched Legacy in sGRB afterglows... continues to this day!

## sGRB 241113A



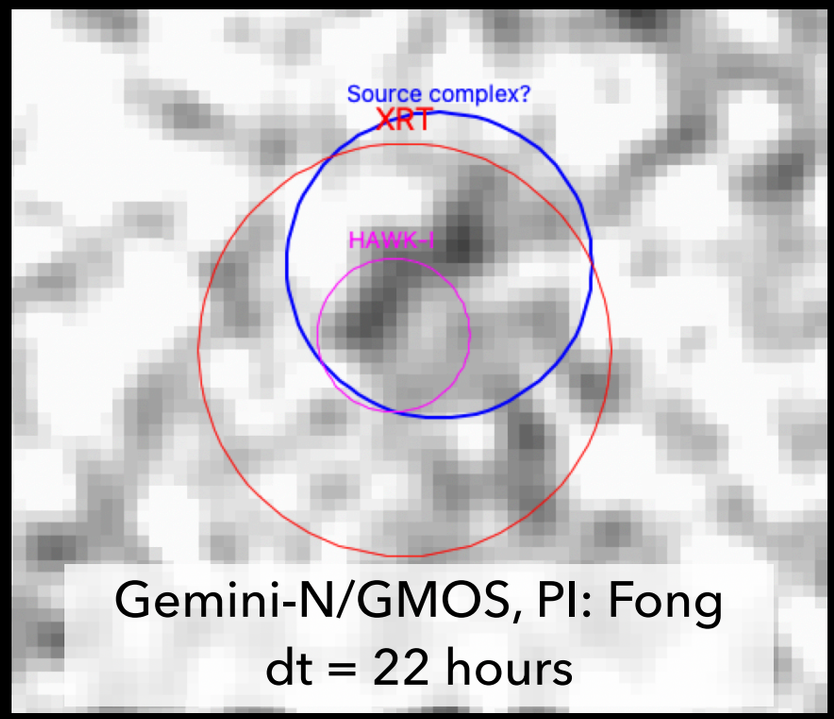




Rapid-response of Swift enabled early AG detections

Deep Gemini follow-up constrains decline rate

4 Swift sGRBs in last 5 months

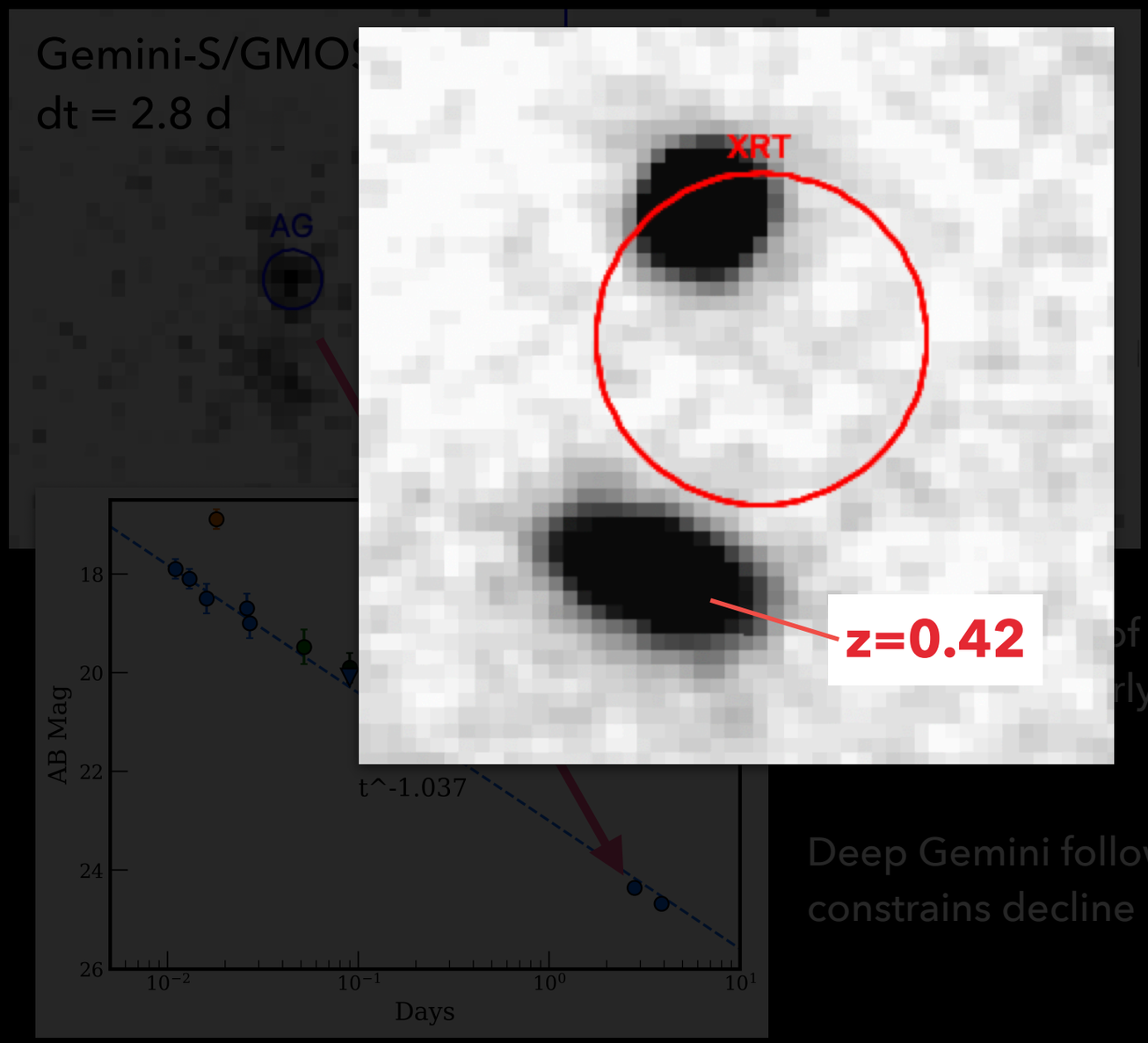
## sGRB 250128B




XRT accuracy enables to identify r~25.4 mag host –> dwarf or high-z?
(Rastinejad et al. GCN 39088)

# Swift's Untouched Legacy in sGRB afterglows... continues to this day!

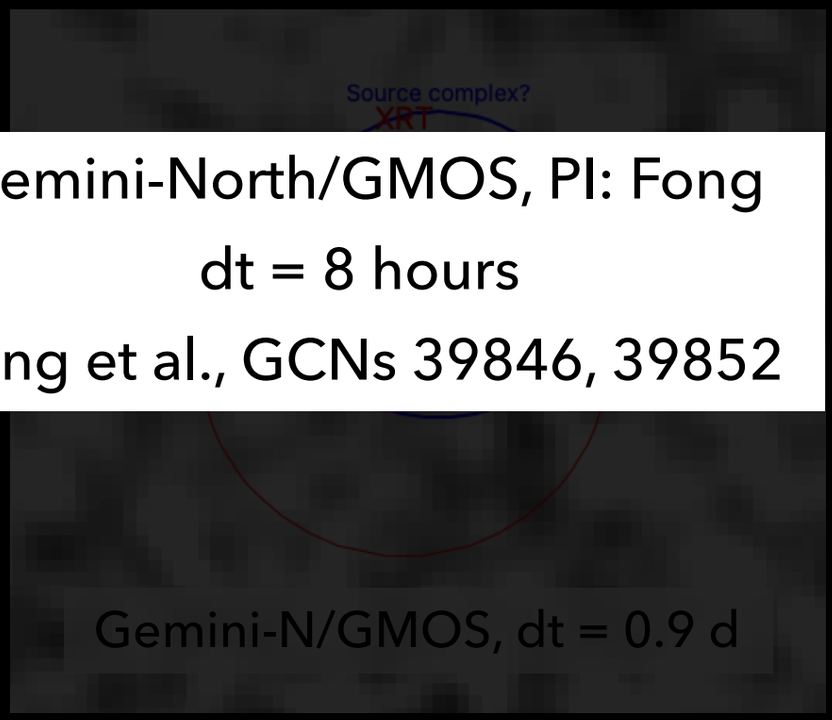
## sGRB 250322A




Deep Gemini follow-up constrains decline rate

**5** Swift sGRBs in last 5 months

## sGRB 250128B




Gemini-North/GMOS, PI: Fong
dt = 8 hours
Fong et al., GCNs 39846, 39852

XRT accuracy enables to identify r~25.4 mag host –> dwarf or high-z? (Rastinejad et al. GCN 39088)

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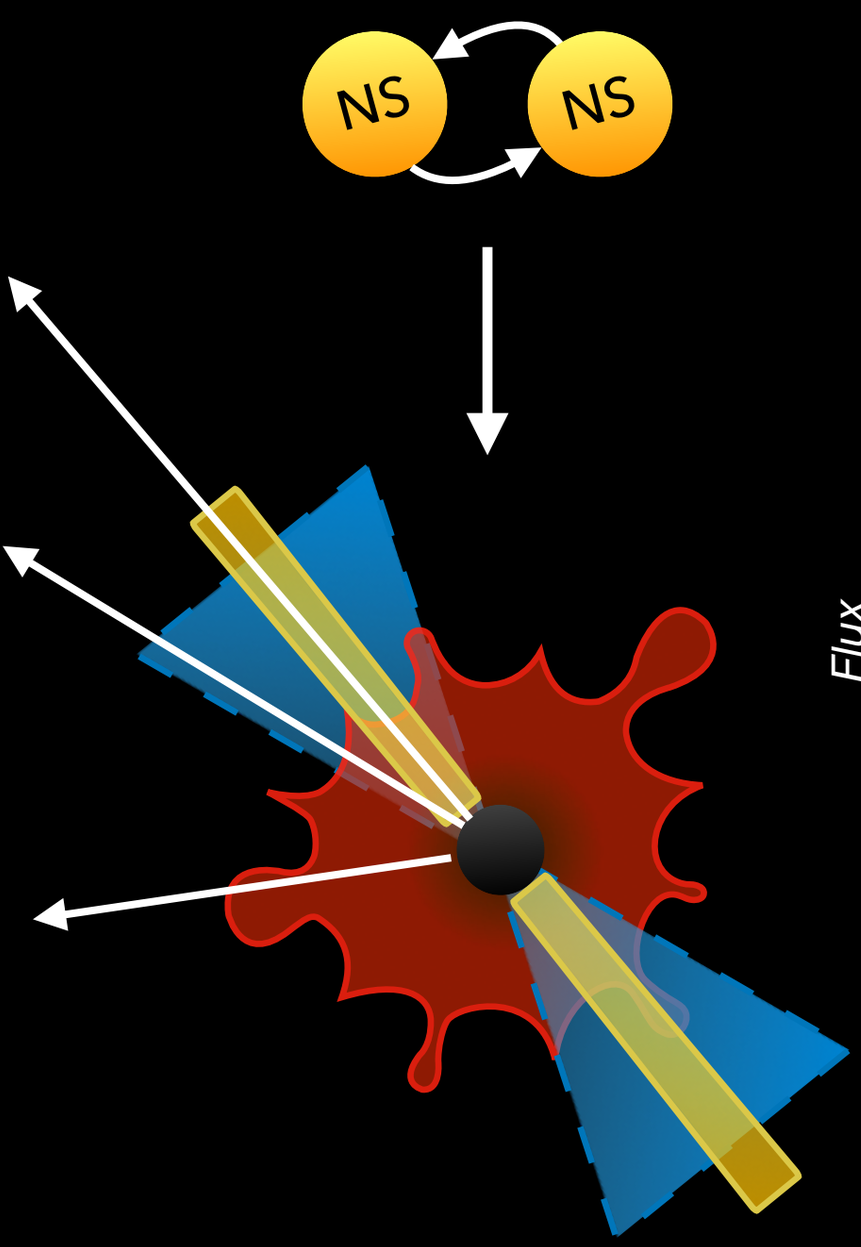
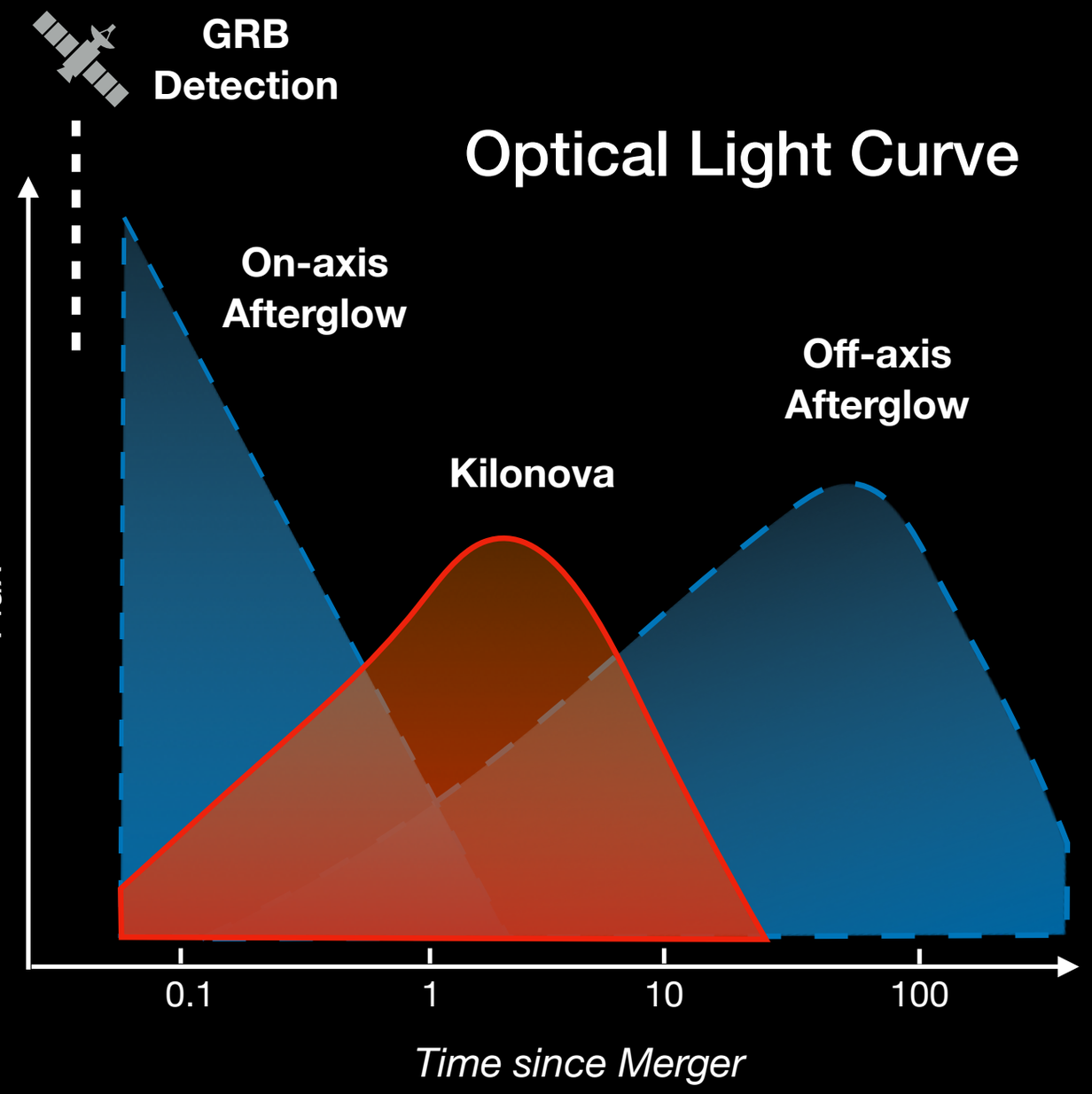
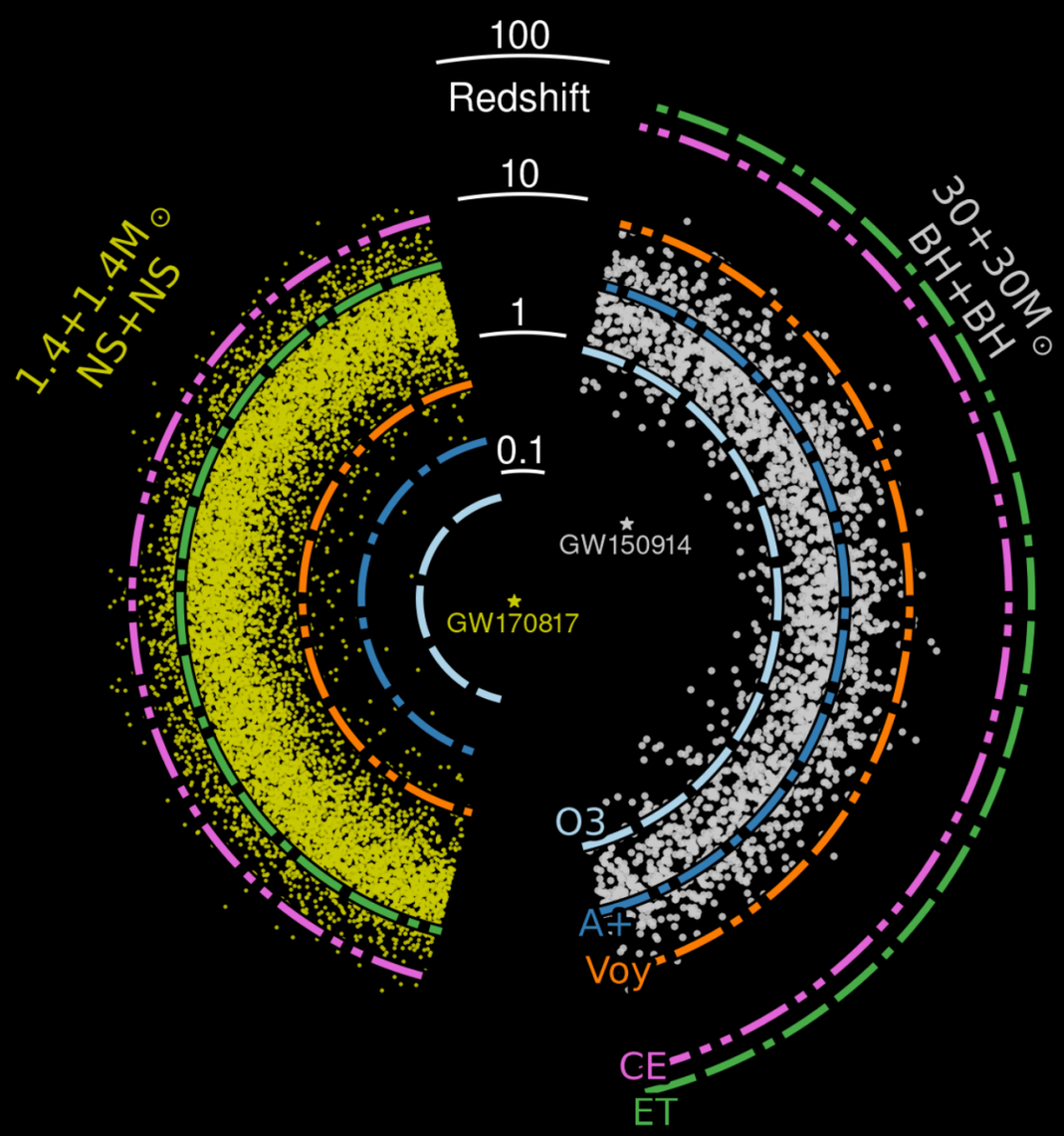
Off-axis afterglows

Kilonova



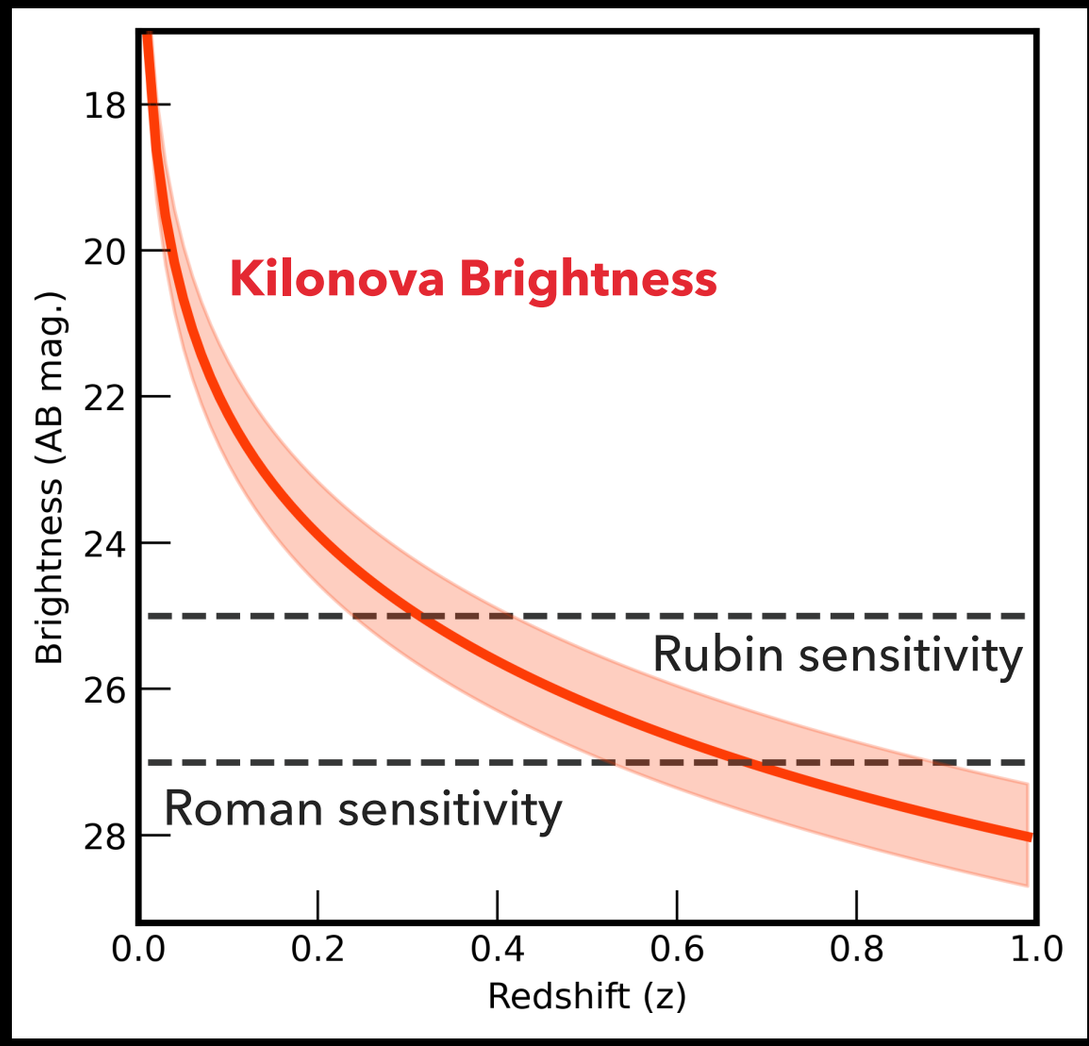



# The Future: Cosmic Explorer + Einstein Telescope will see NS mergers out to z ~ 2



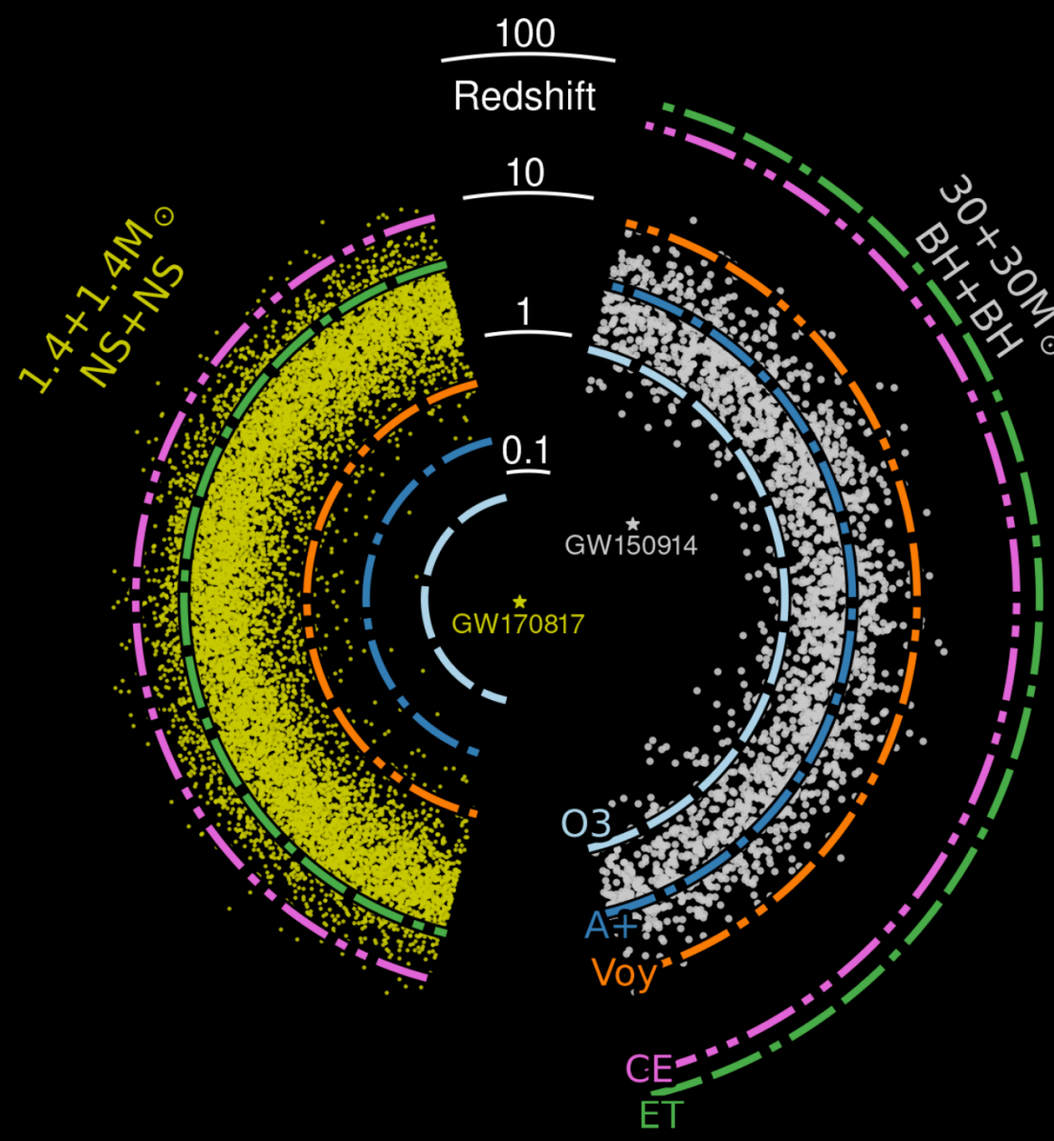

Reitze et al., arXiv: 1903.04615

Updated version: Evans et al. 2021; CE Horizons Study



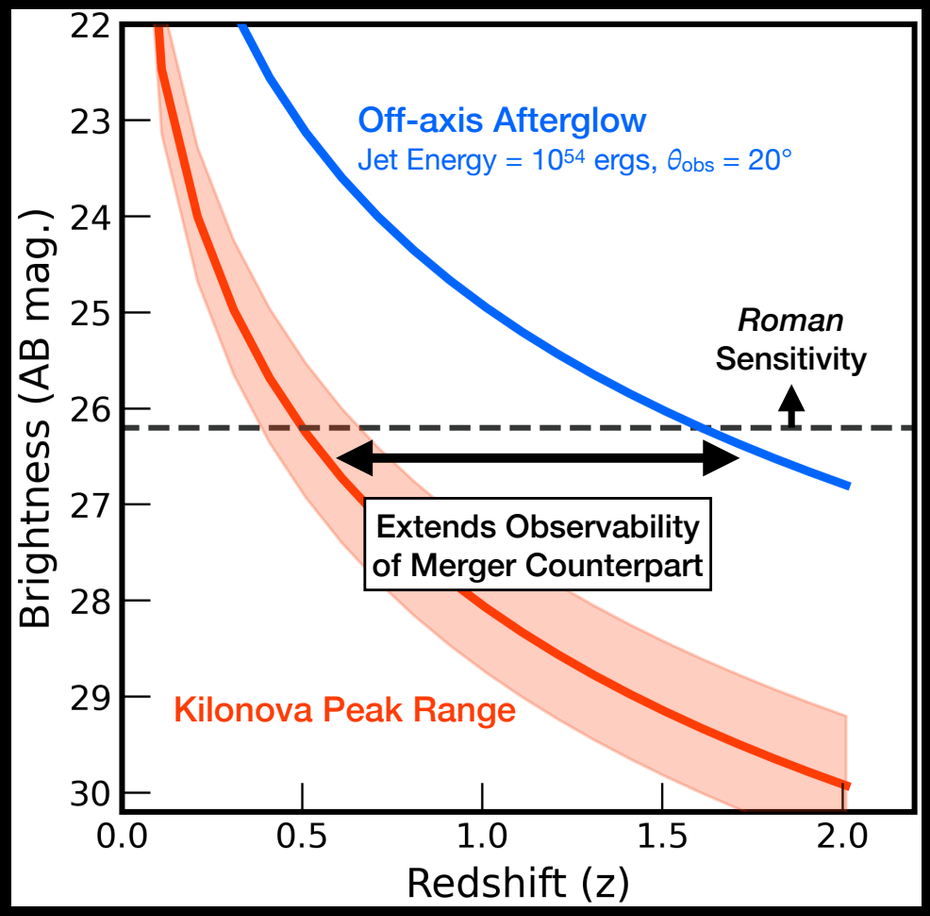

Kilonova too faint for current telescopes at z > 0.6

# The Future: Cosmic Explorer + Einstein Telescope will see NS mergers out to z ~ 2




Reitze et al., arXiv: 1903.04615

Updated version: Evans et al. 2021; CE Horizons Study




Best observational constraints on off-axis afterglows: on-axis Swift afterglows!

*e.g., Rouco-Escorial+23, Morsony+24, Kaur+24*

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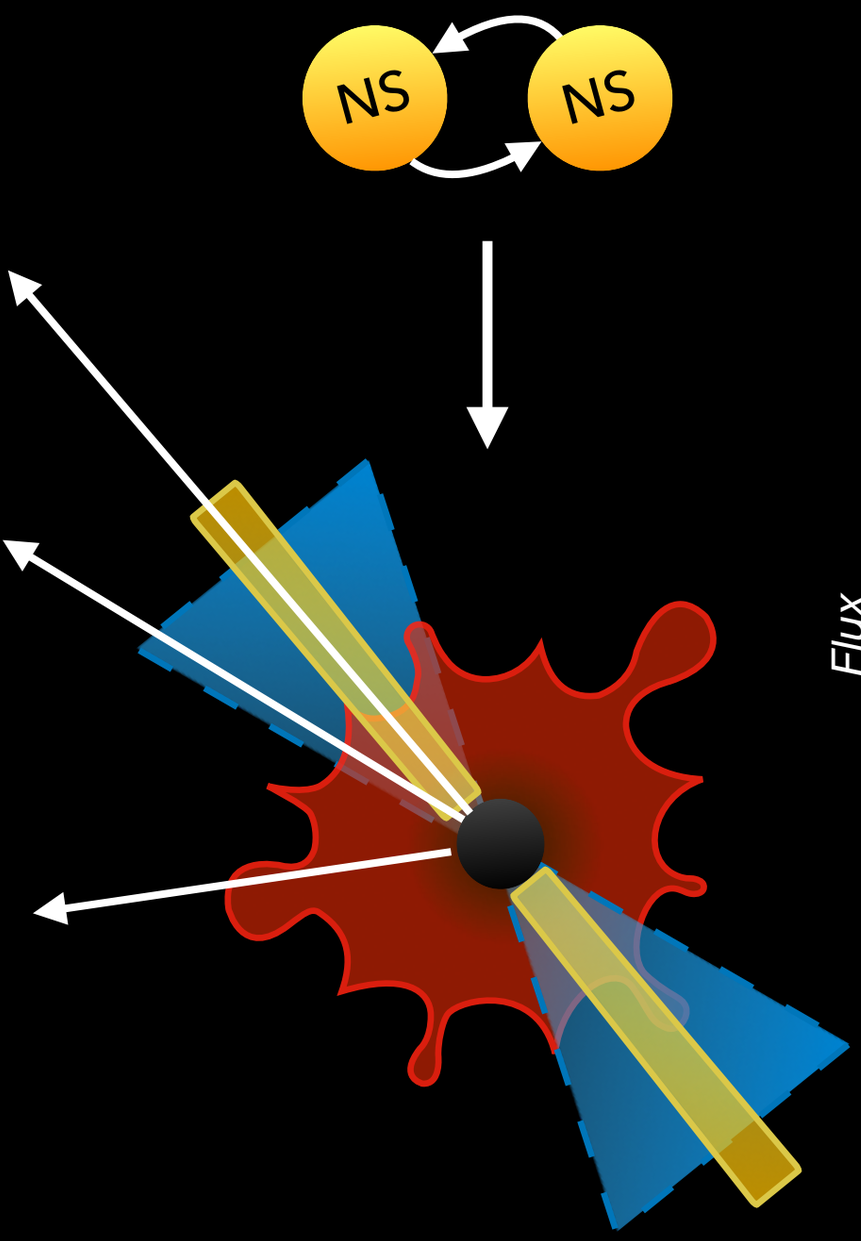
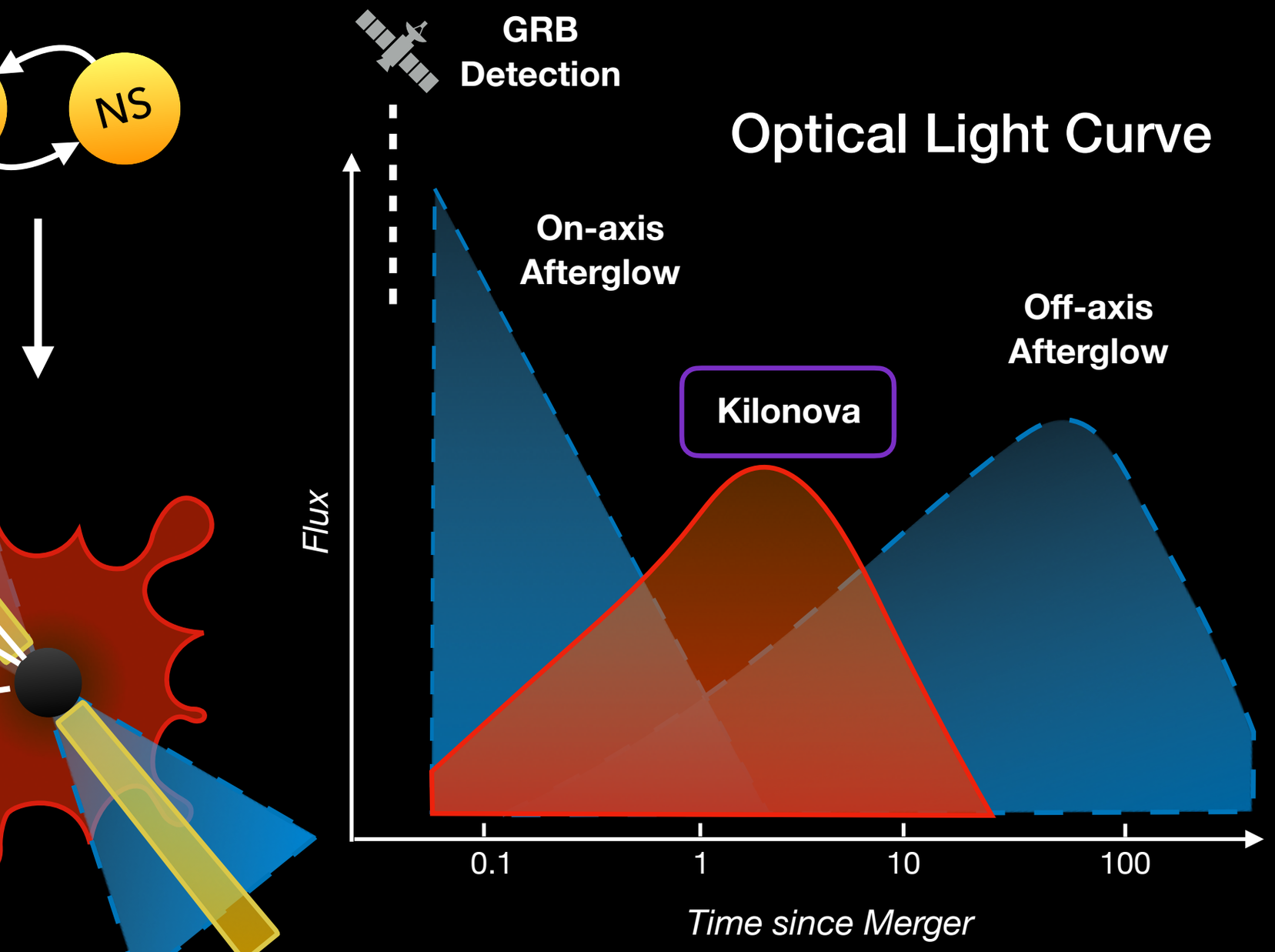
**Potential Counterpart**

GRBs + on-axis afterglows

Off-axis afterglows

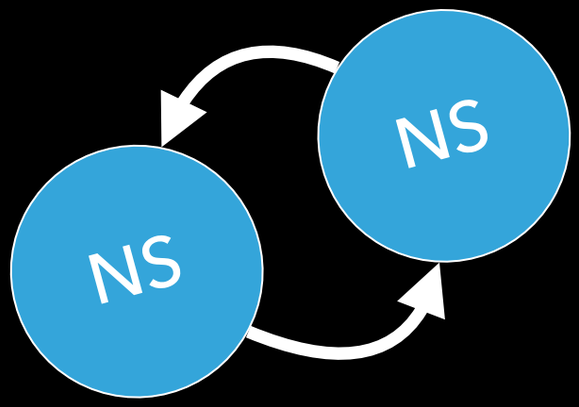
Kilonova



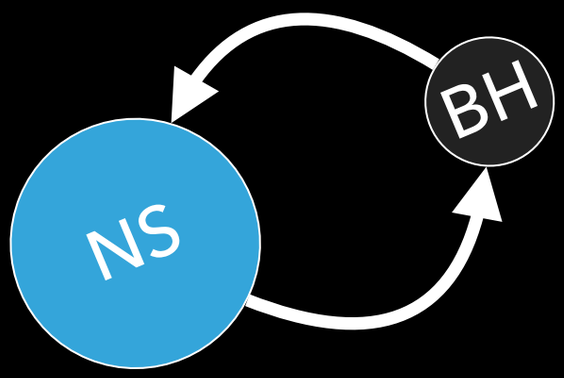
# PREDICTIONS FOR KILONOVA DIVERISTY

## Progenitor Diversity




Merge

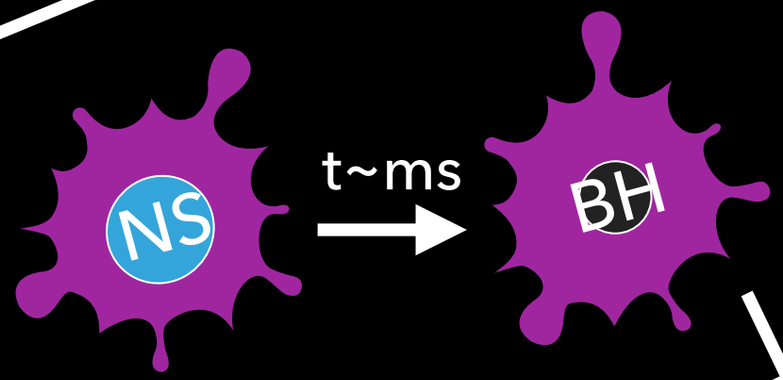
e.g., Mass ratio, spin, magnetic field strength




Merge

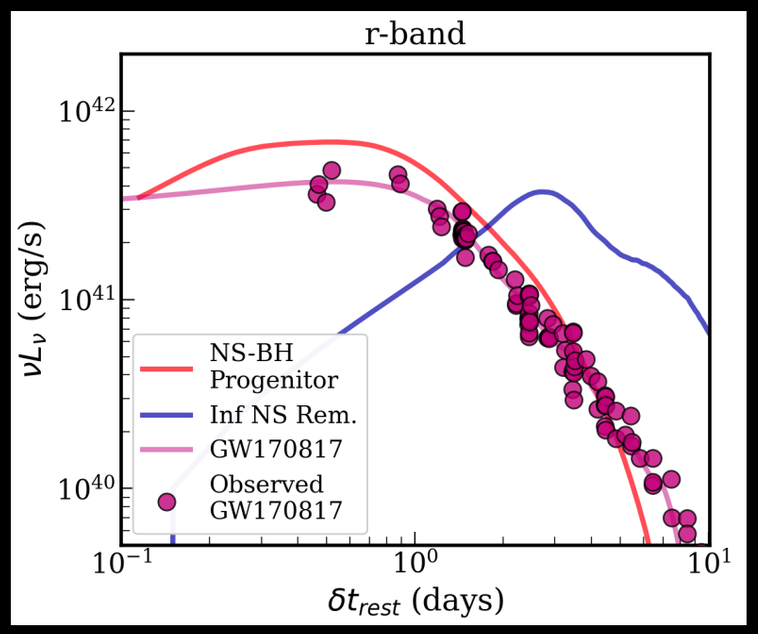
e.g., Metzger+19, Shibata+19, Kawaguchi+22

## Remnant Diversity

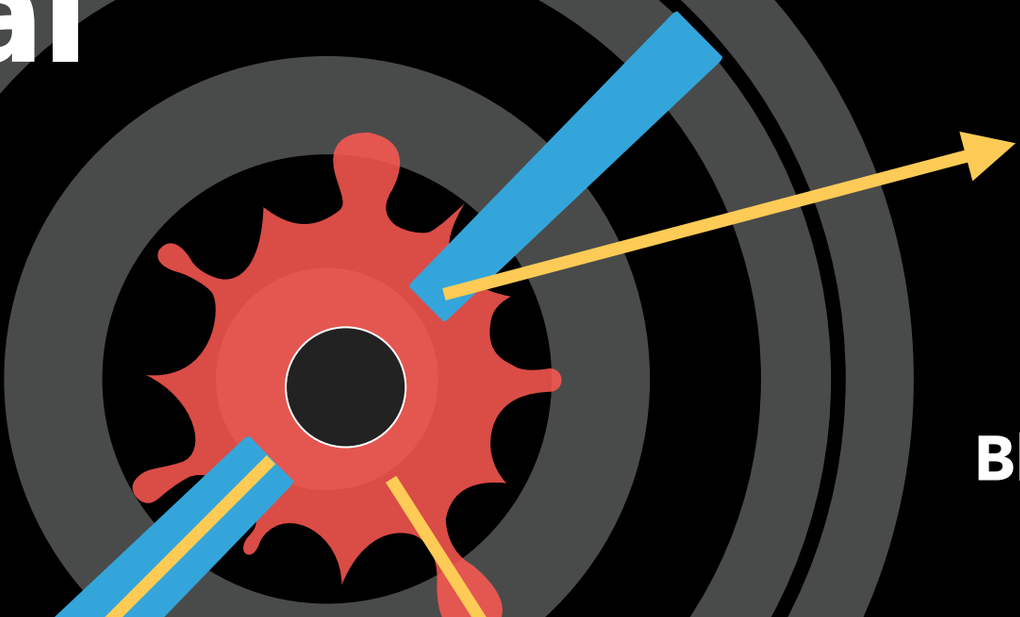





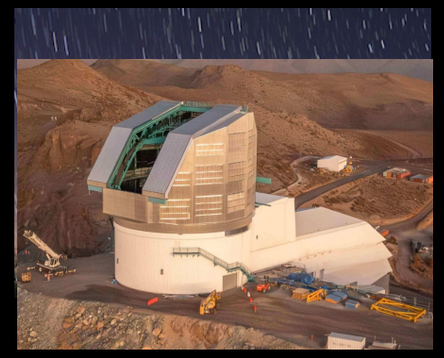

## *Observables*



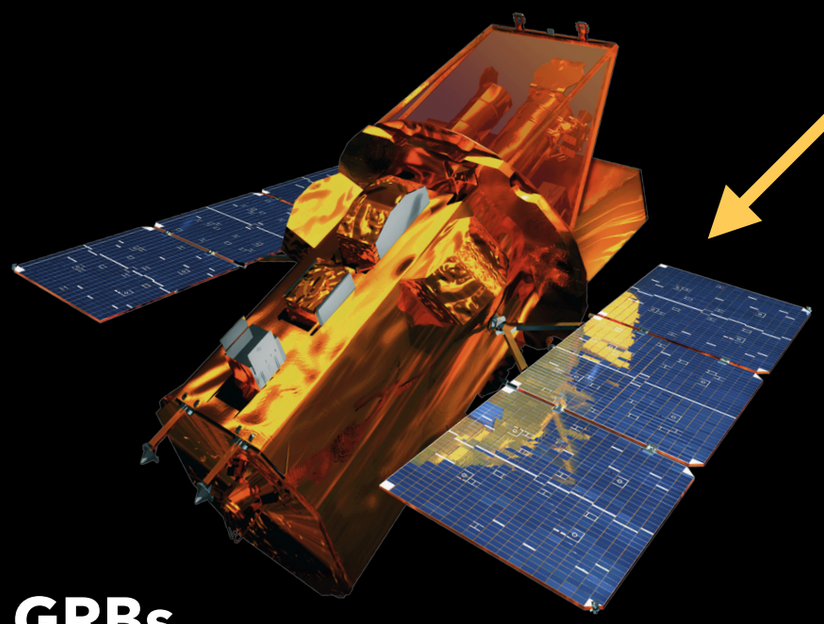
# Observational Searches for NS Mergers



e.g., Smartt+17, Yang+18, Andreoni+21



**Blind Searches in Large Surveys**



**GRBs**

*Swift*

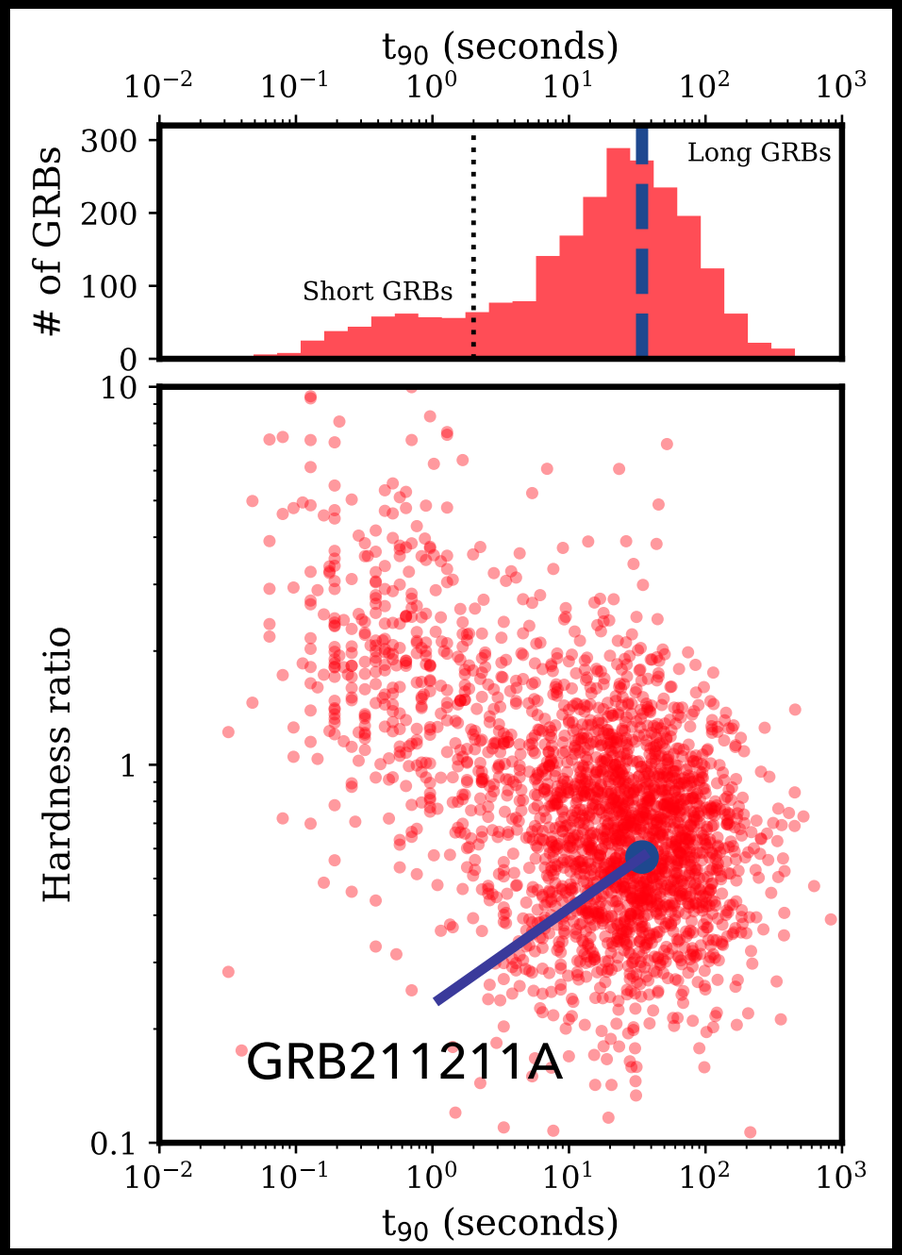

LIGO

Virgo

**Gravitational Waves**

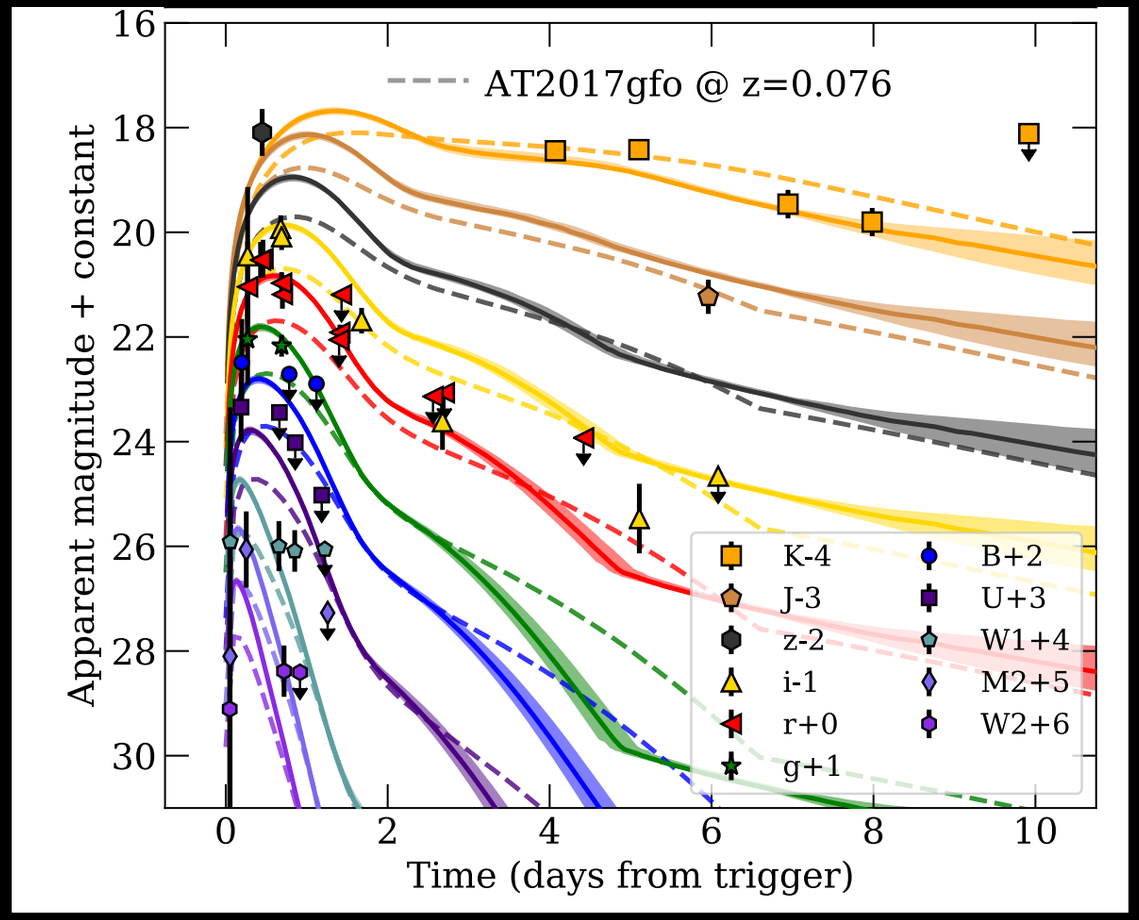
# GRB 211211A:

## The 50-s GRB 211211A with a kilonova counterpart



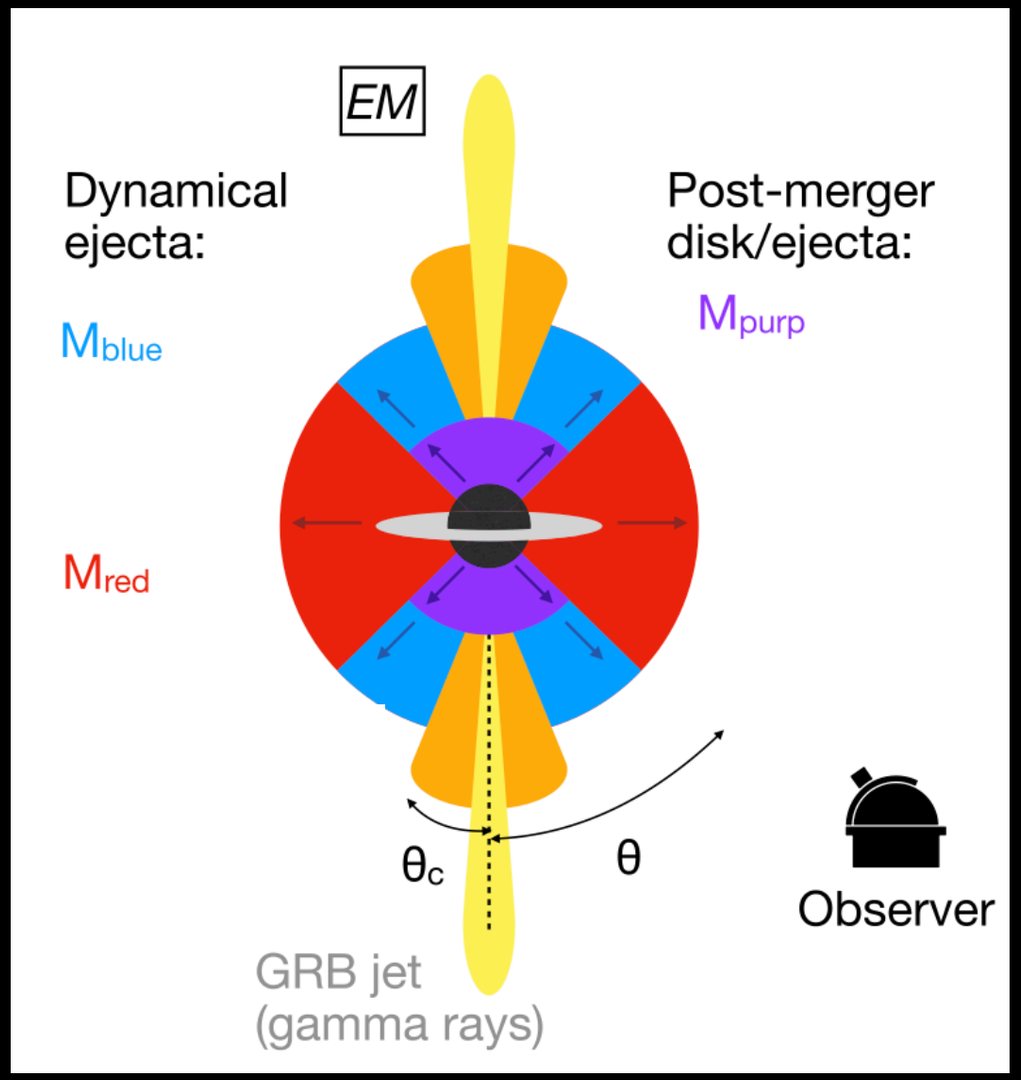

*Rastinejad+22*

## Kilonova red + fades like AT2017gfo

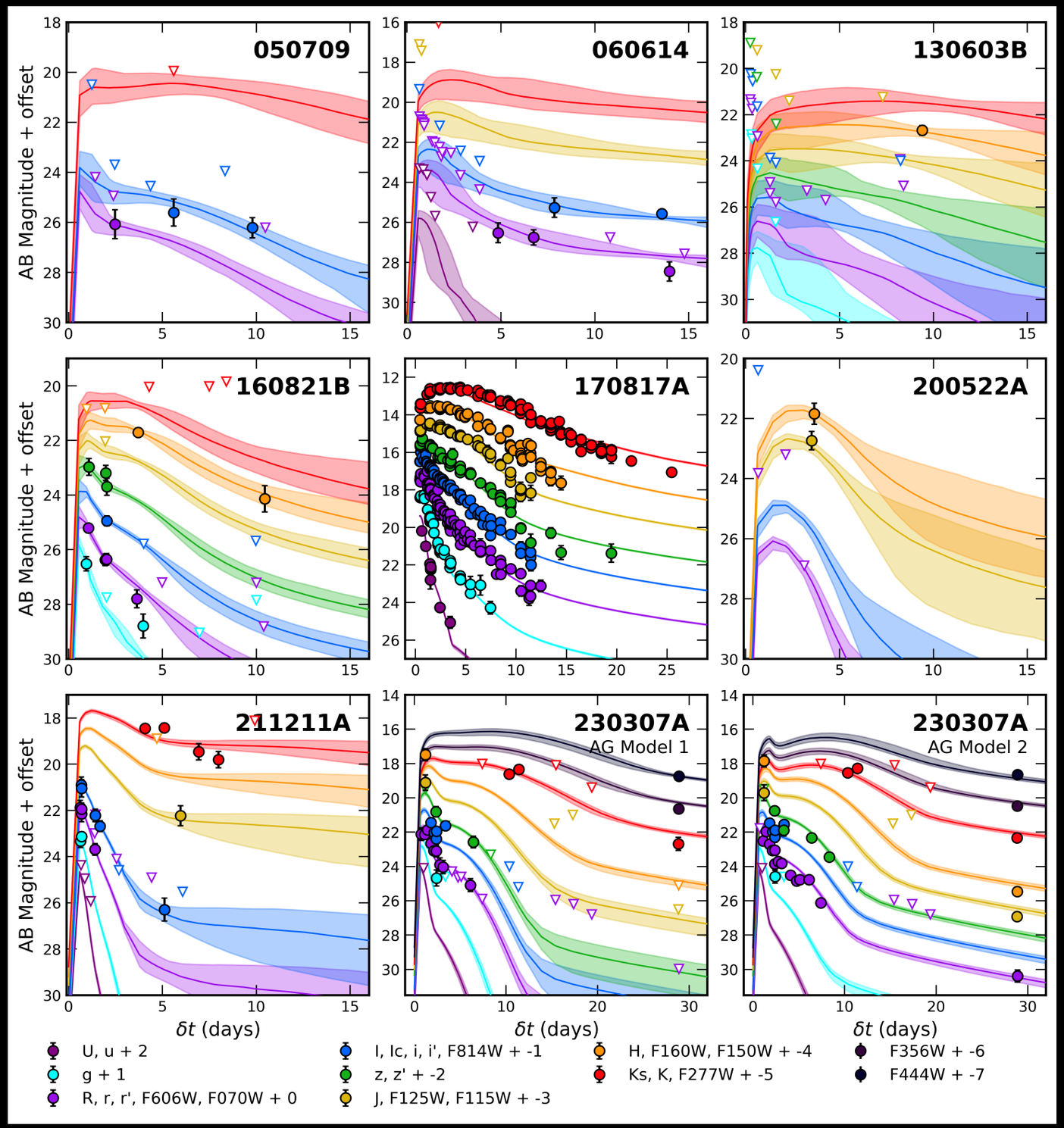



**–> diversity in the merger systems that create GRBs?**

# Uniform Modeling of eight kilonovae

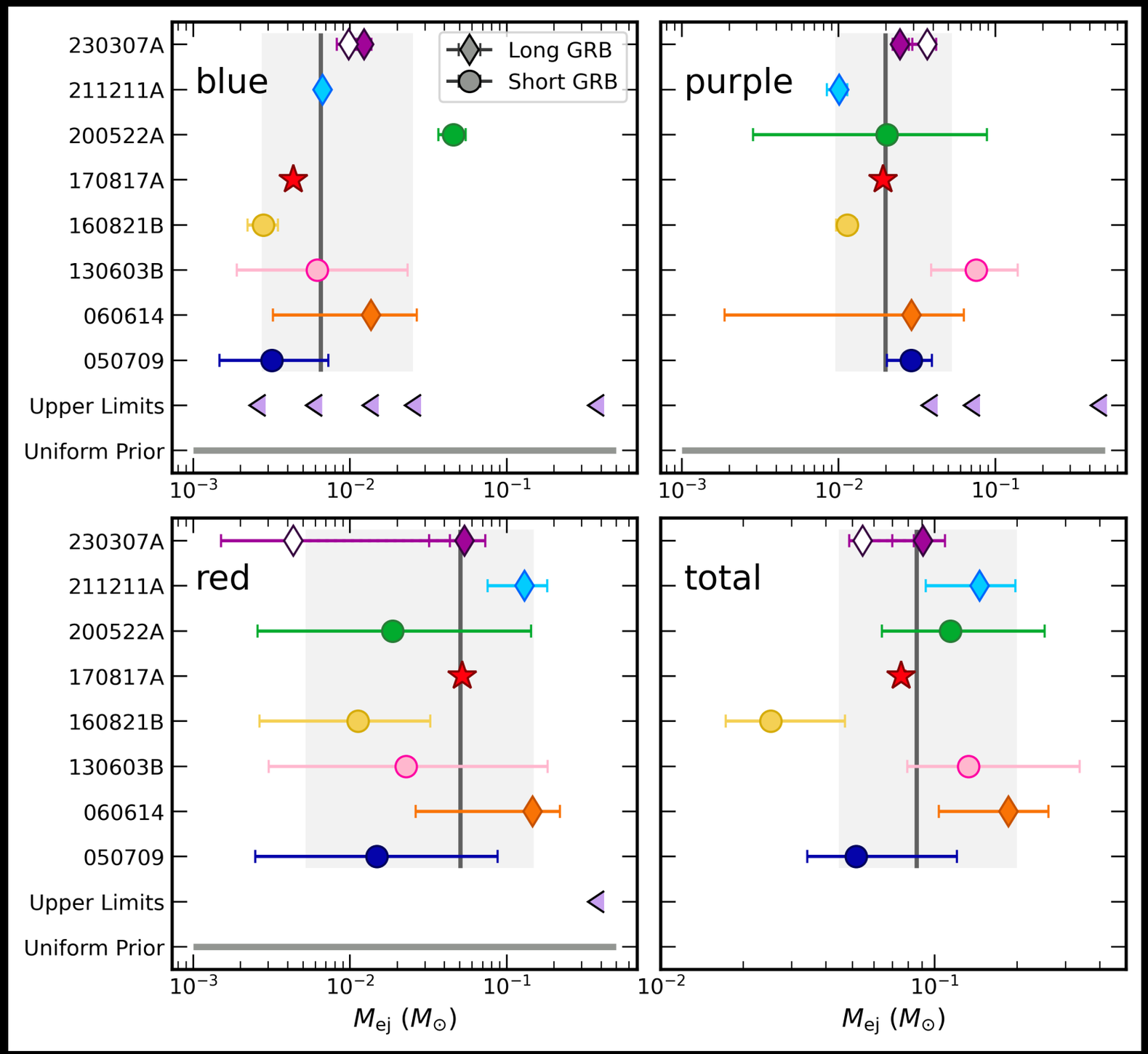



*Villar+17, Nicholl+21*




*Rastinejad+25*

# Uniform Modeling of eight kilonovae

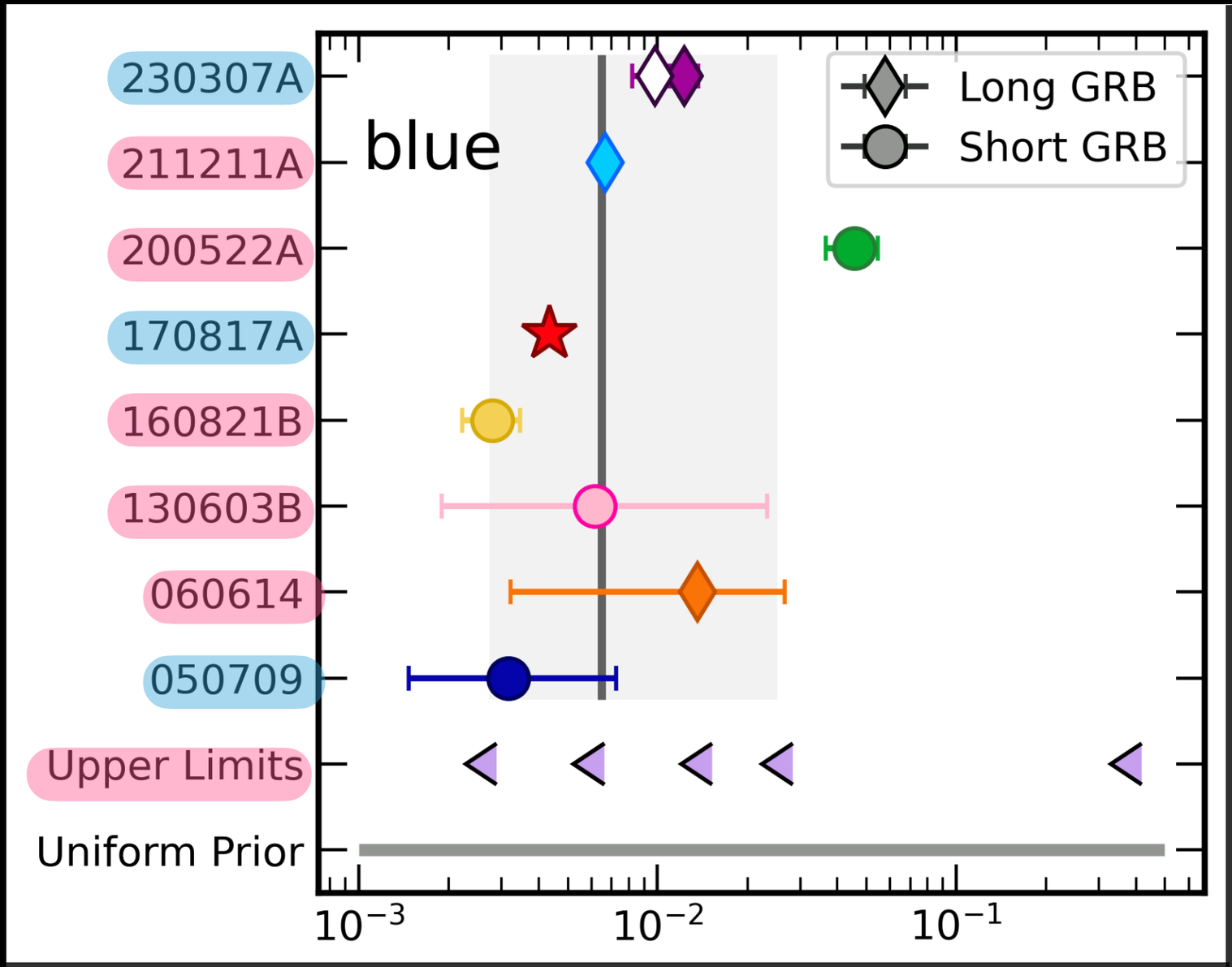


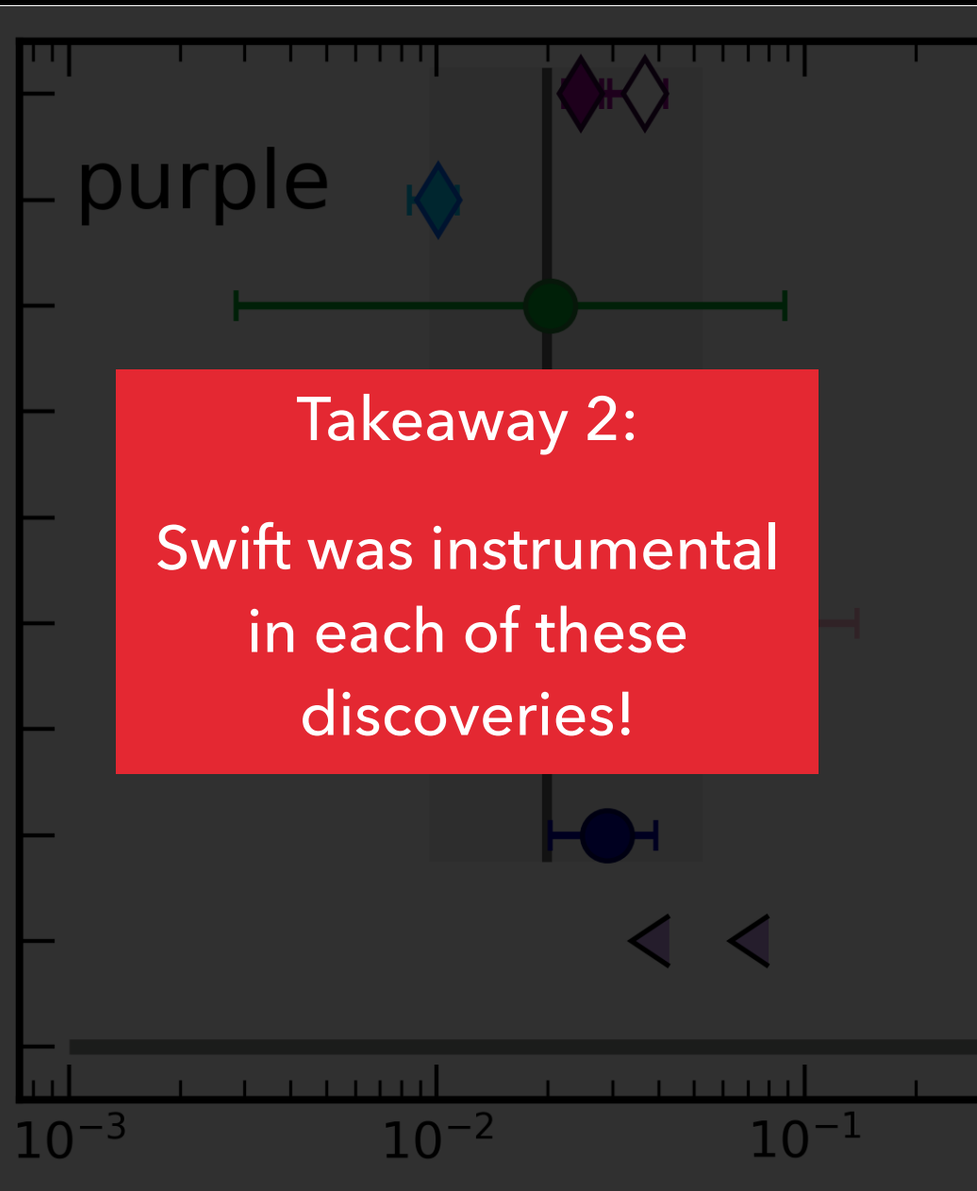

Takeaway 1:

GW170817 is an "average" kilonova compared to the sample

*Rastinejad+25*

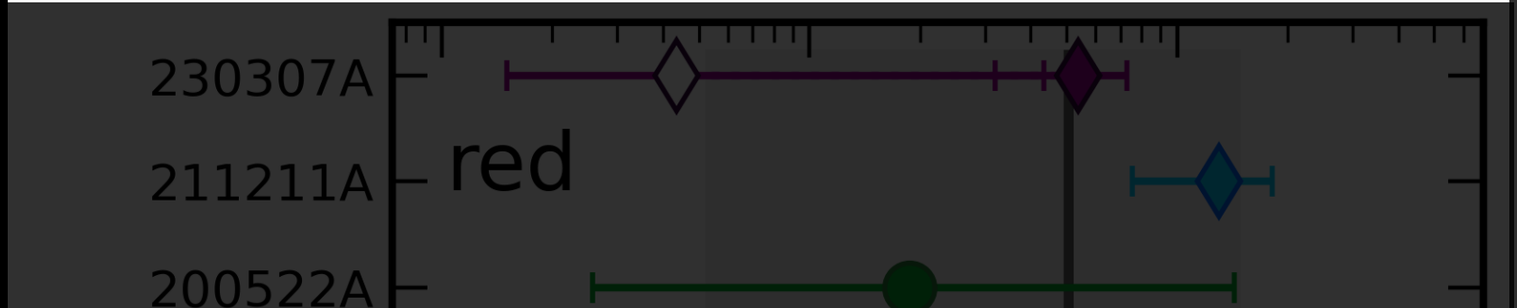
# Uniform Modeling of eight kilonovae

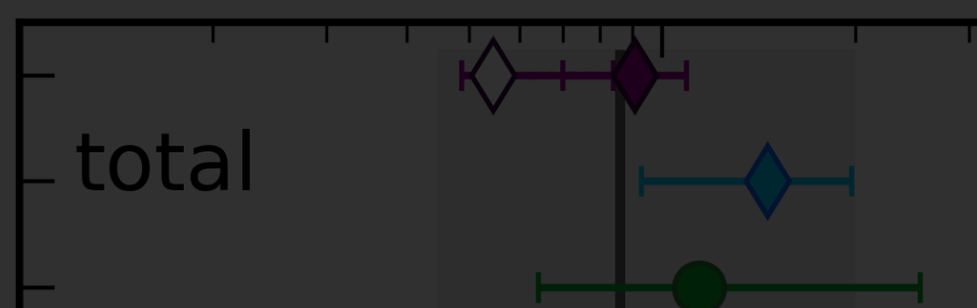



Takeaway 2:

Swift was instrumental in each of these discoveries!



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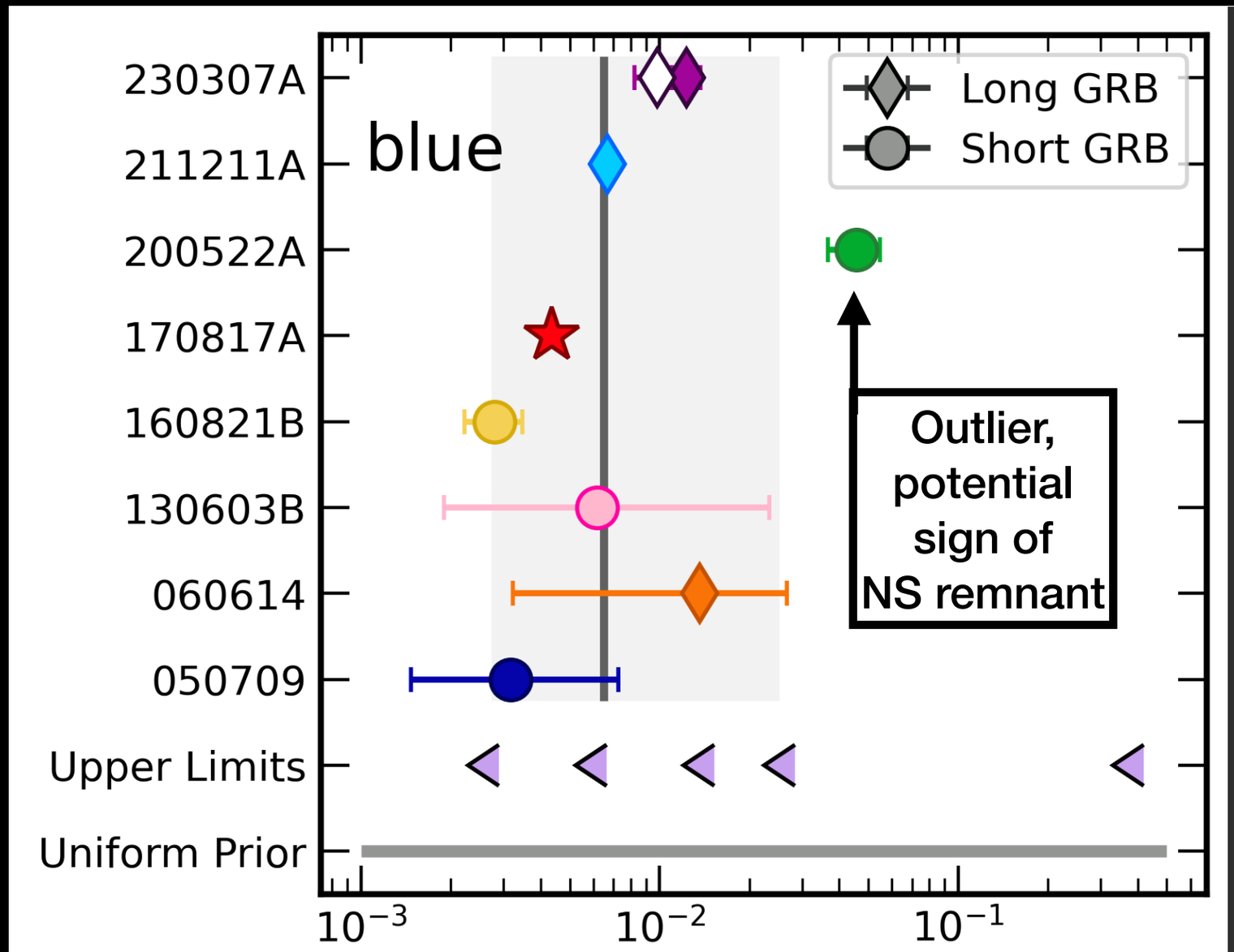
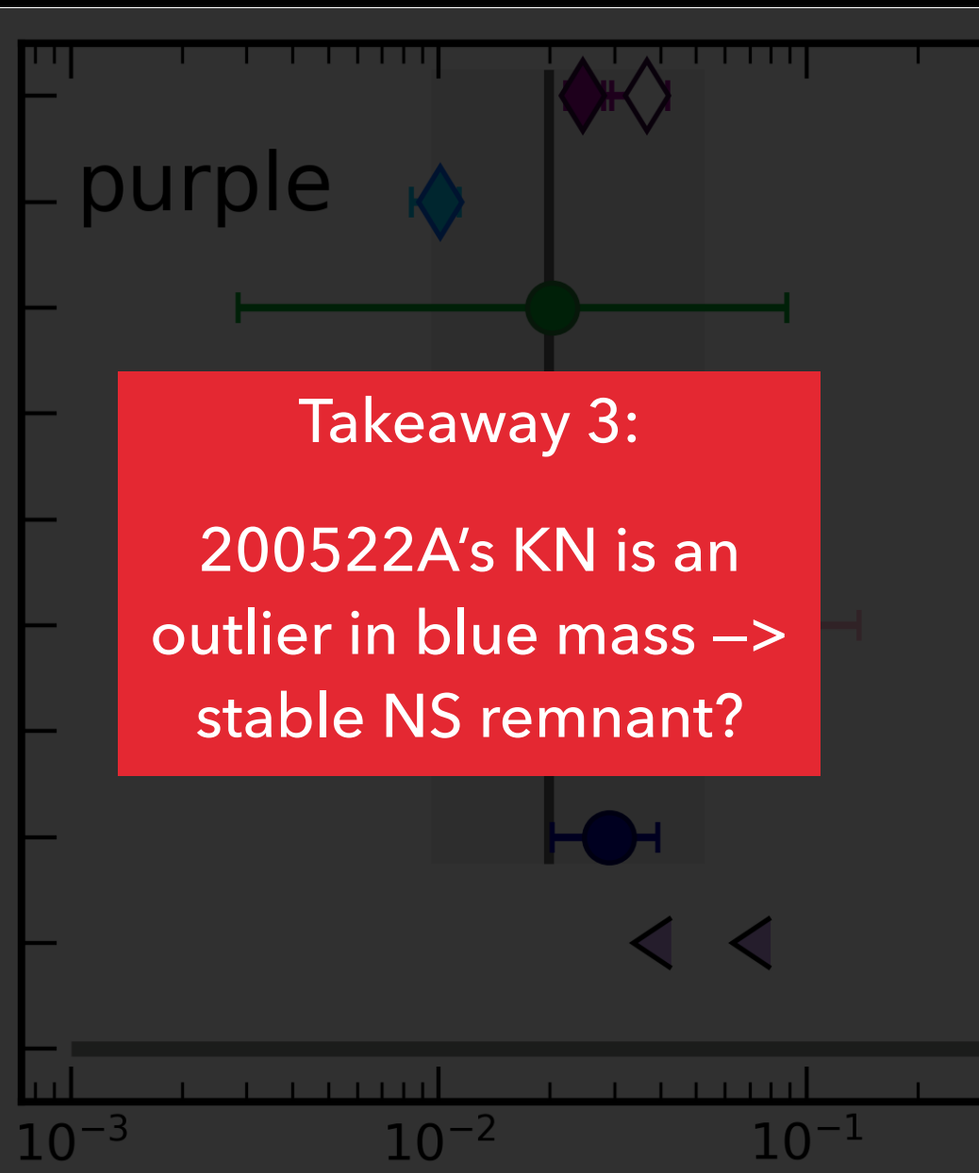
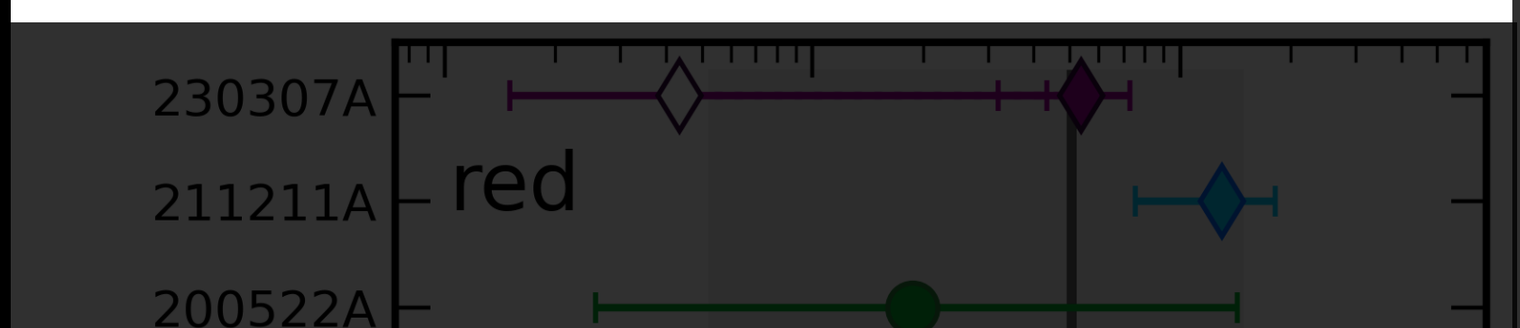
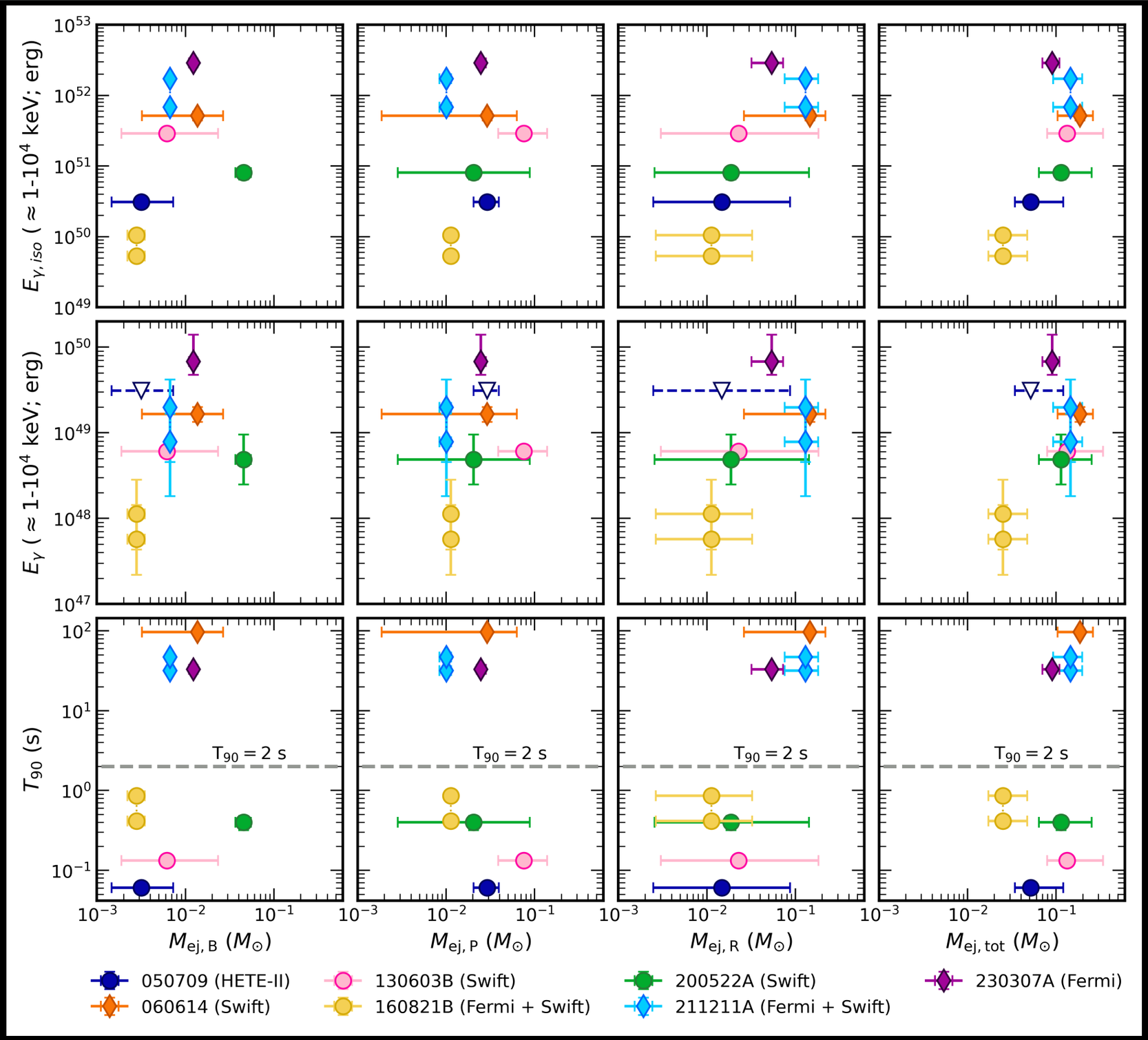



Takeaway 3:

200522A's KN is an outlier in blue mass –> stable NS remnant?




*Rastinejad+25*

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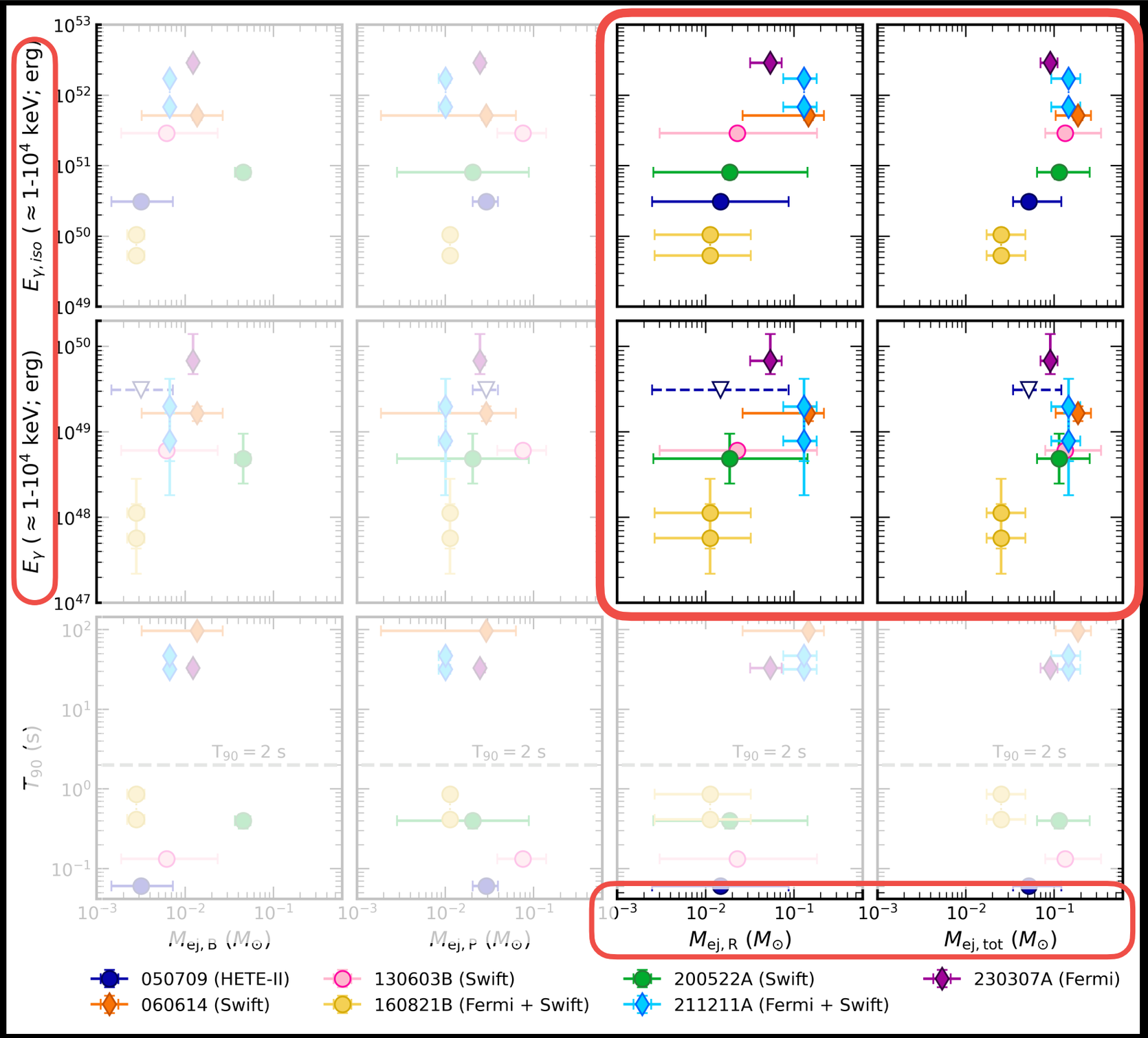
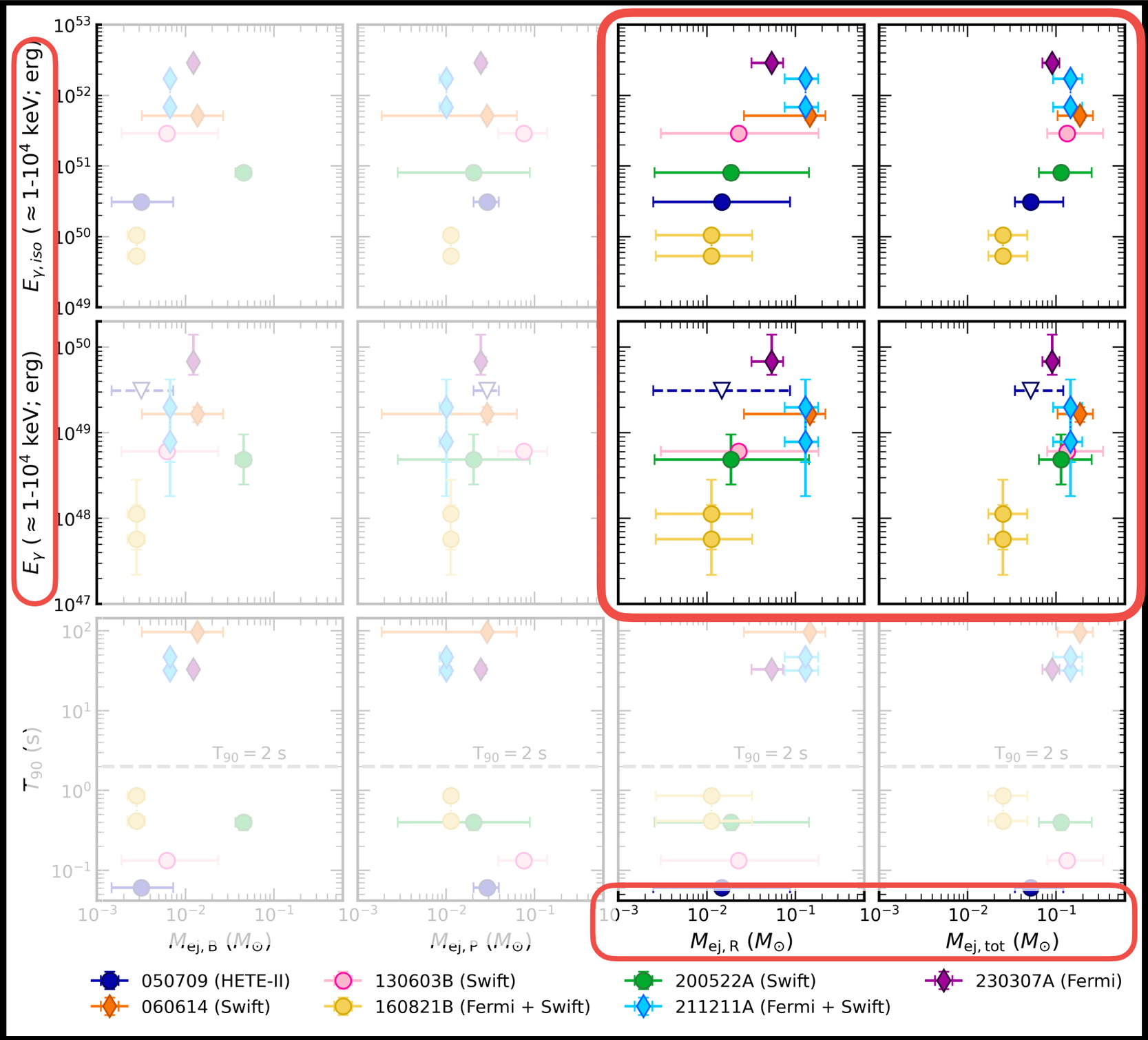



Trend between GRB energy and dynamical ejecta

*Rastinejad+25*

# Uniform Modeling of eight kilonovae

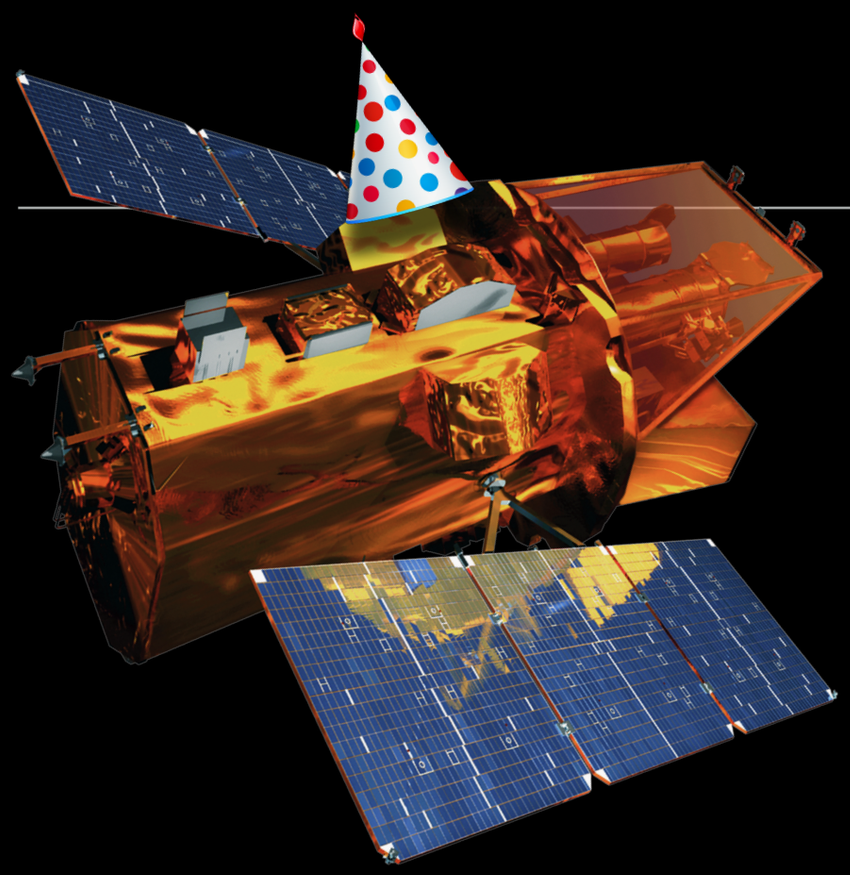



Trend between GRB energy and dynamical ejecta

Predicted outcome for asymmetric compact object binary progenitor (Gottlieb+23)

Asymmetric binaries seen in GWs: GW190425, GW230529

*Rastinejad+25*



# Conclusions

Thank you Swift team! Here's to another 20 years!

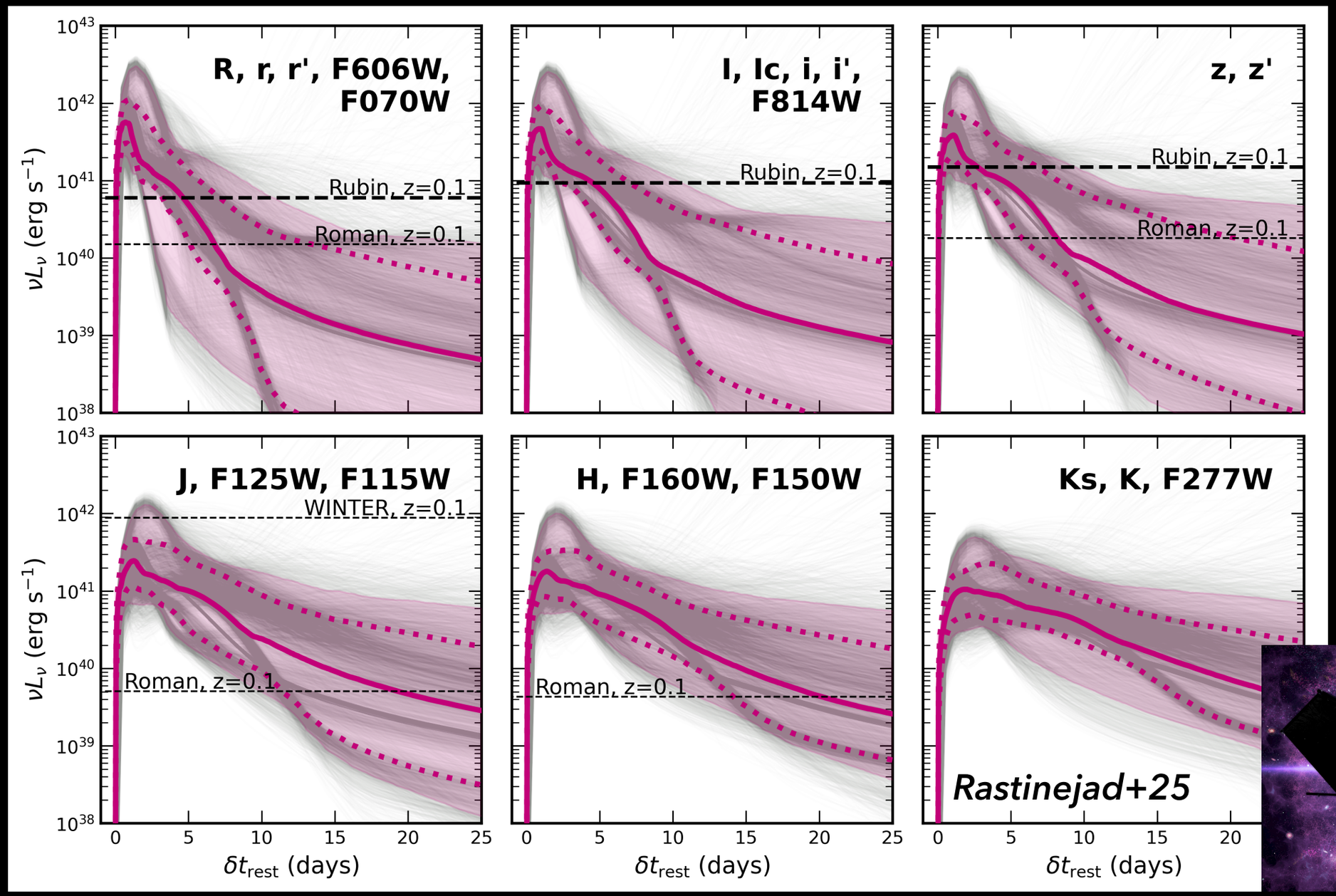
Takeaways:

Swift short GRB afterglow diversity = critical for next-generation MMA predictions.

Swift has enabled rapid follow-up discoveries of kilonovae following both short and long GRBs, revealing unprecedented diversity

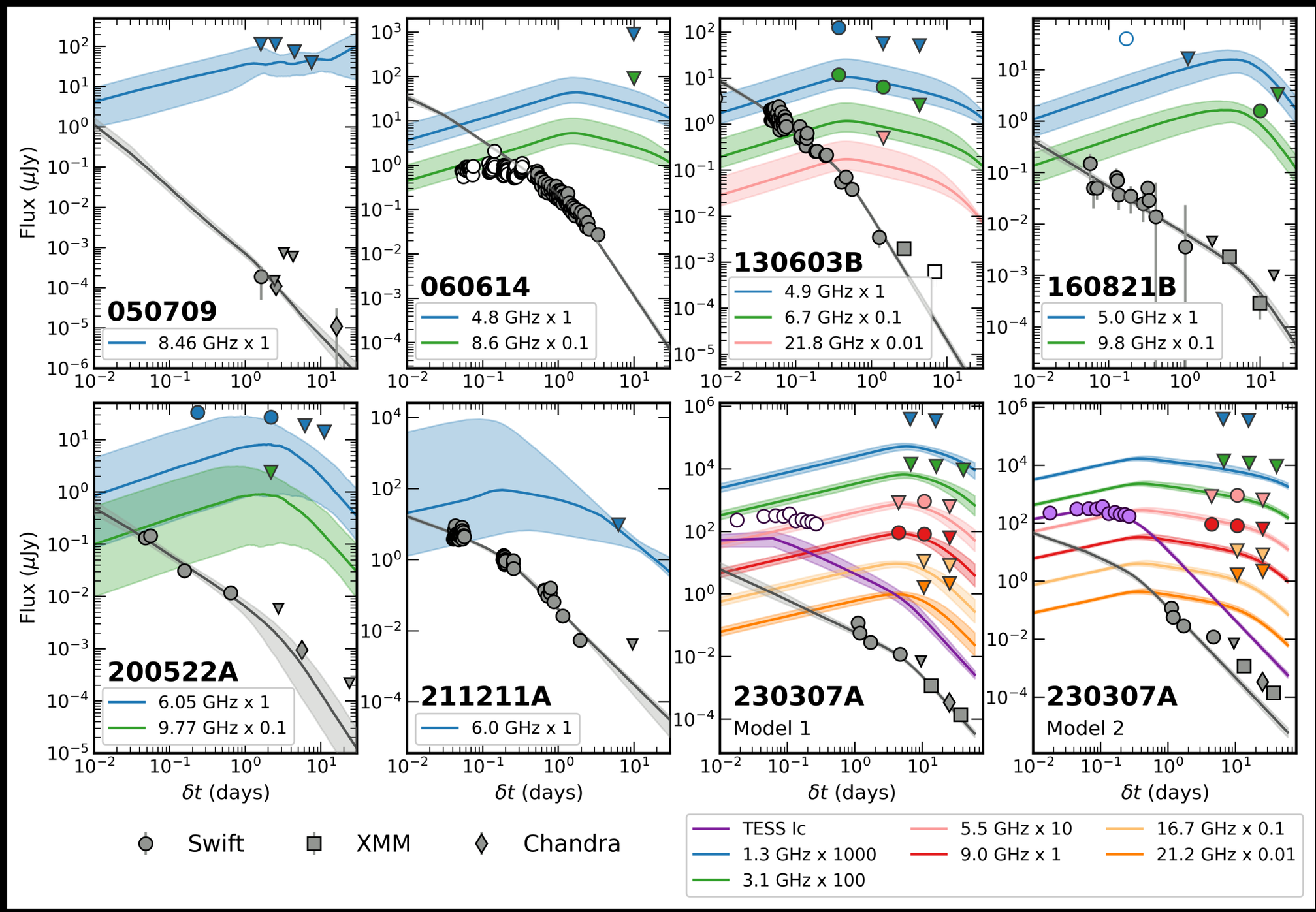
Thanks to a large team, including Wen-fai Fong + the Fong research group, Andrew Levan, Charlie Kilpatrick, Matt Nicholl, Brian Metzger

# Uniform Modeling of eight kilonovae




With 5-day cadence + NIR coverage, Roman can observe the full luminosity distribution of KNe over 2-3 epochs –> sufficient for ejecta mass constraints

# Observed Diversity of Kilonovae

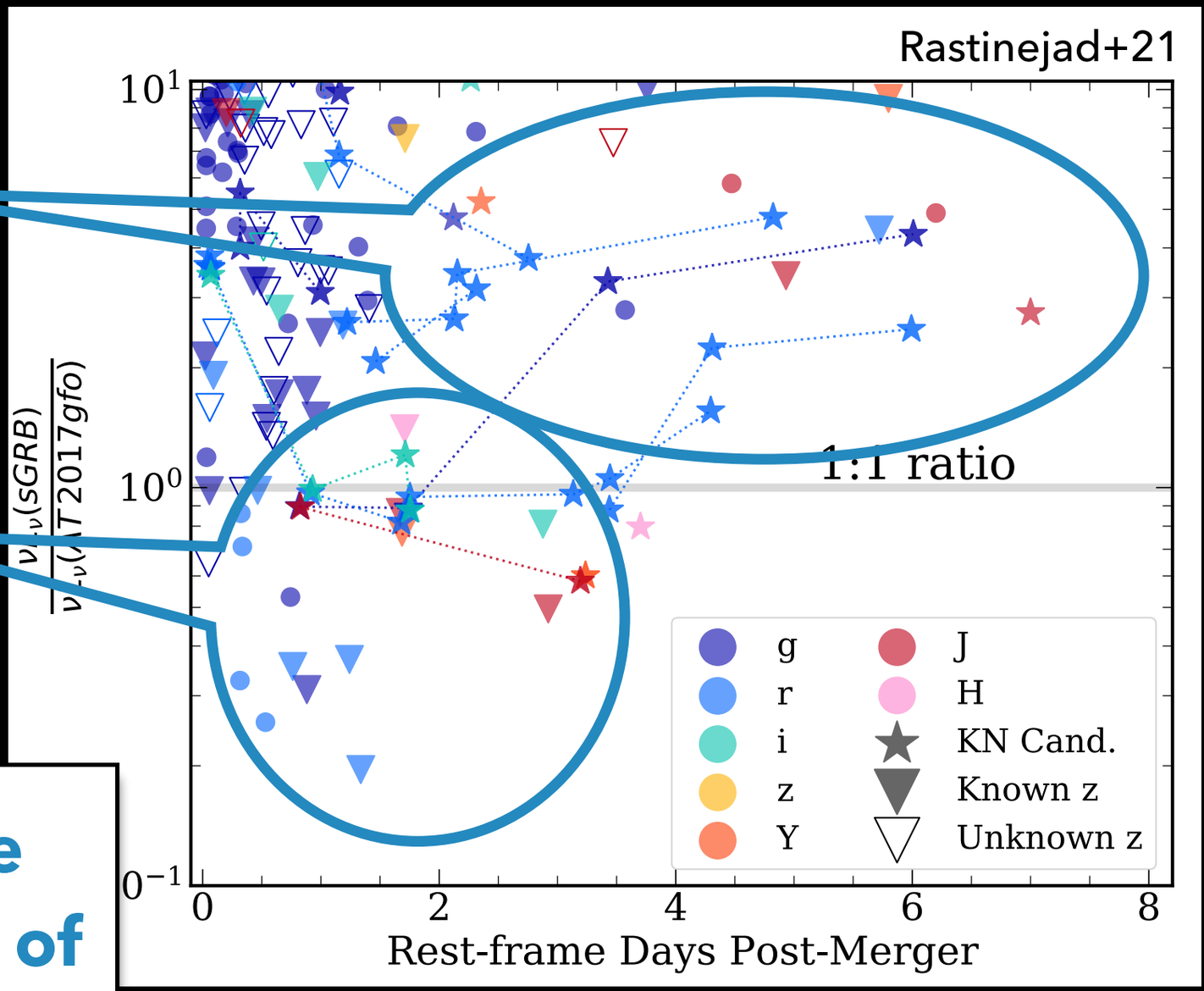



*Rastinejad+25*

# Afterglow + Kilonova Diversity Observed from Short GRBs

Kilonova candidates are more luminous in bluer bands than AT2017gfo

Deep upper limits of 10 bursts fall below 1:1 ratio




**Rest-frame optical KNe observations show span of ~100 in luminosity**

See also Gompertz+18, Ascenzi+19, Rossi+20