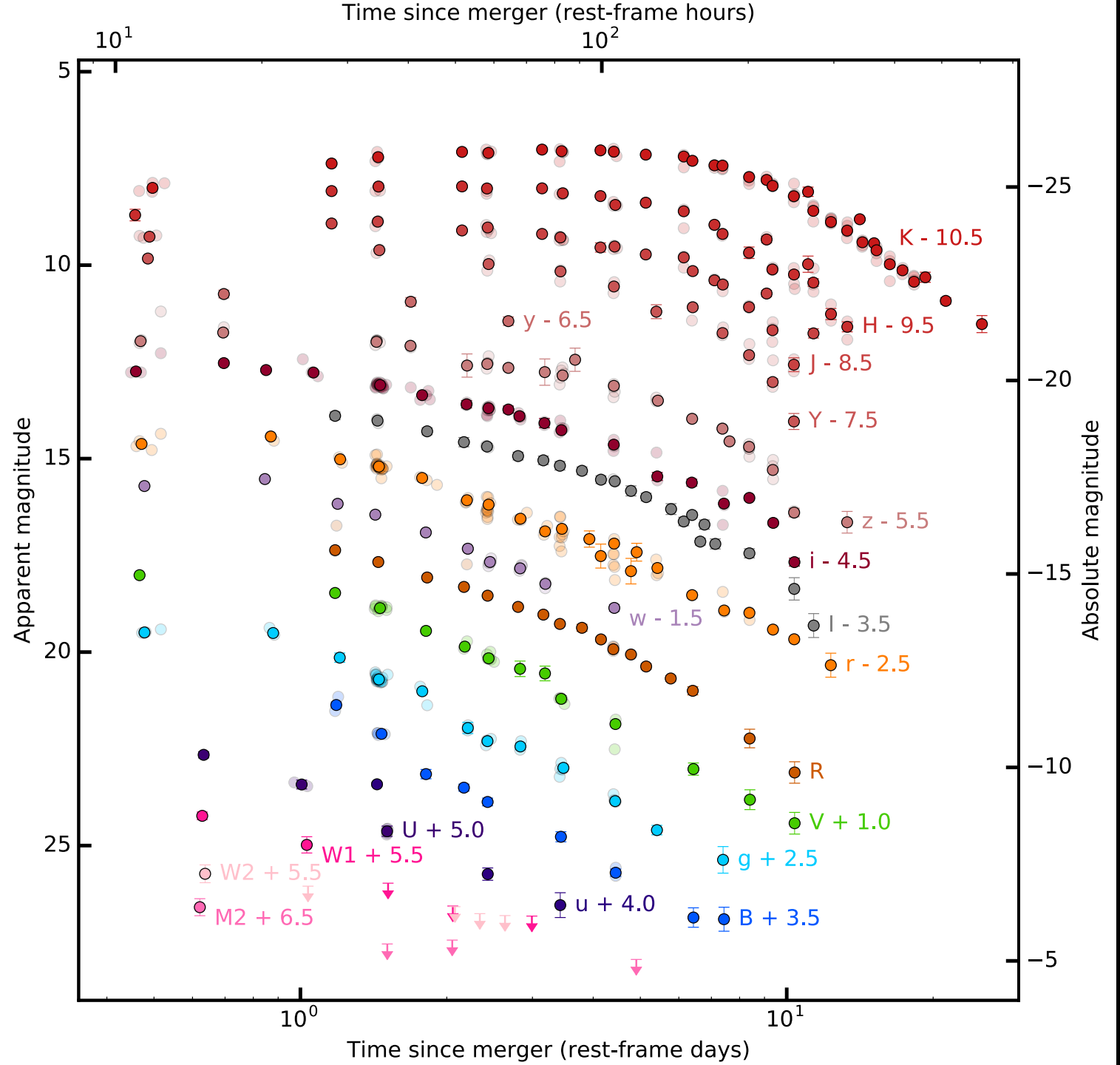
Very Early Optical & UV Observations of Kilonovae are Important

Here's Why

Iair ("ya-eer") Arcavi
UC Santa Barbara & Las Cumbres Observatory
(soon: Tel Aviv University)



Compilation from:
Arcavi 2018

Data from:
Andreoni et al. 2017,
Arcavi et al. 2017,
Cowperthwaite et al. 2017,
Coulter et al. 2017,
Diaz et al. 2017,
Drout et al. 2017,
Evans et al. 2017,
Hu et al. 2017,
Kasliwal et al. 2017,
Lipunov et al. 2017,
Pian et al. 2017,
Pozanenko et al. 2017,
Shapee et al. 2017,
Smartt et al. 2017,
Tanvir et al. 2017,
Troja et al. 2017,
Utsumi et al. 2017,
Valenti et al. 2017.

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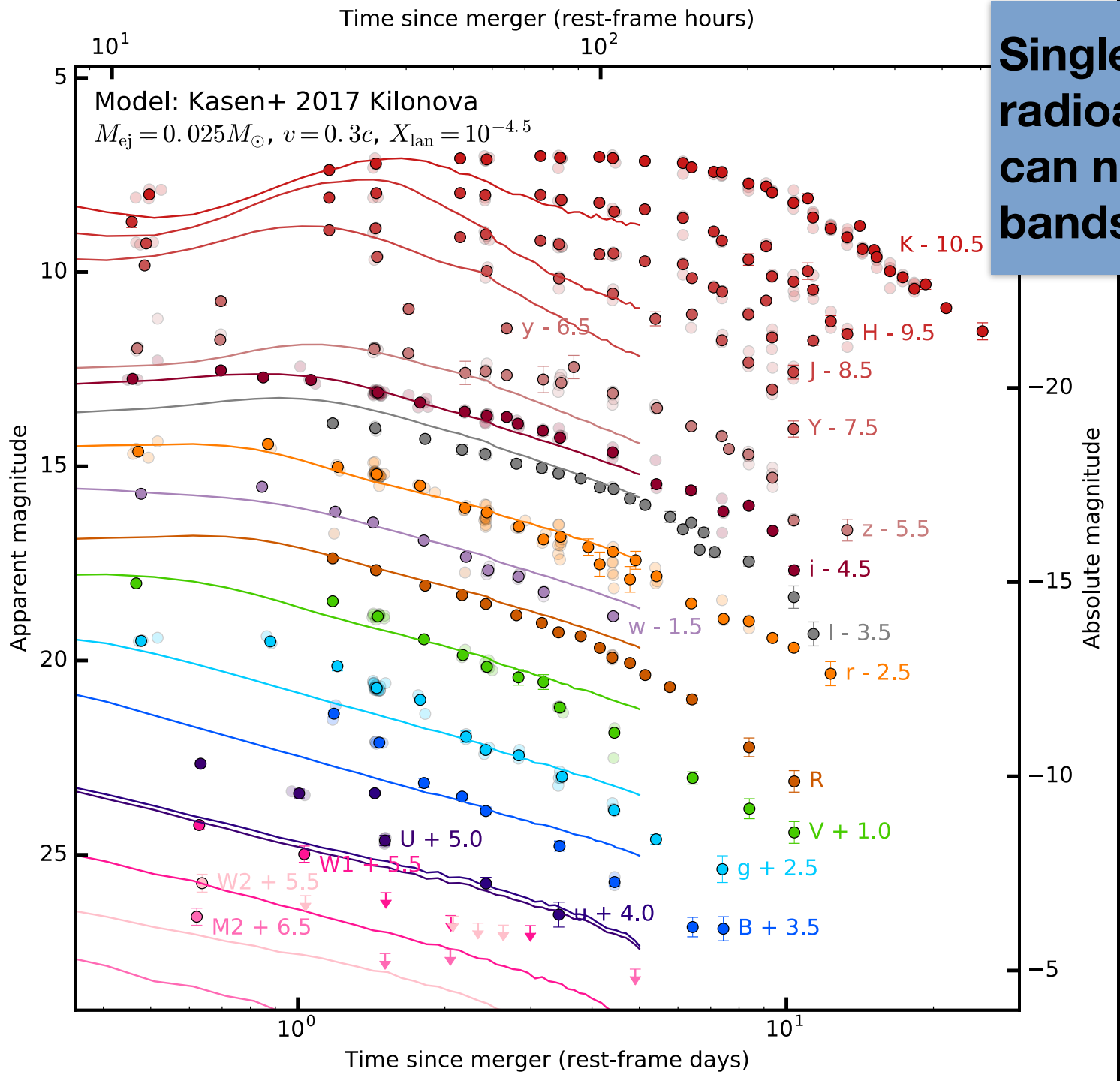
kilonovae.space



Single component radioactive decay can not explain all bands.

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Arcavi 2018

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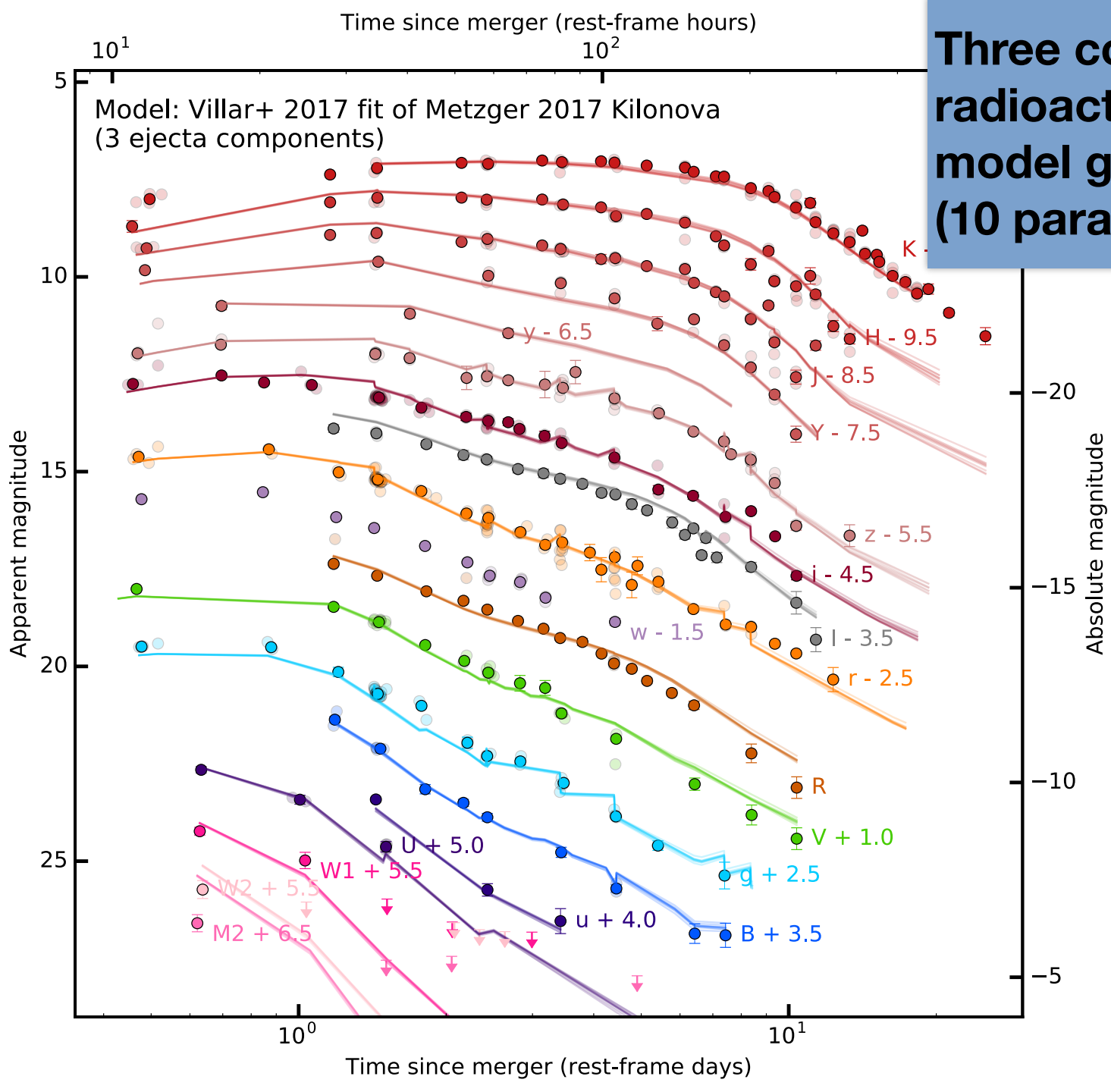
Three component radioactive decay model gives a better fit (10 parameters).



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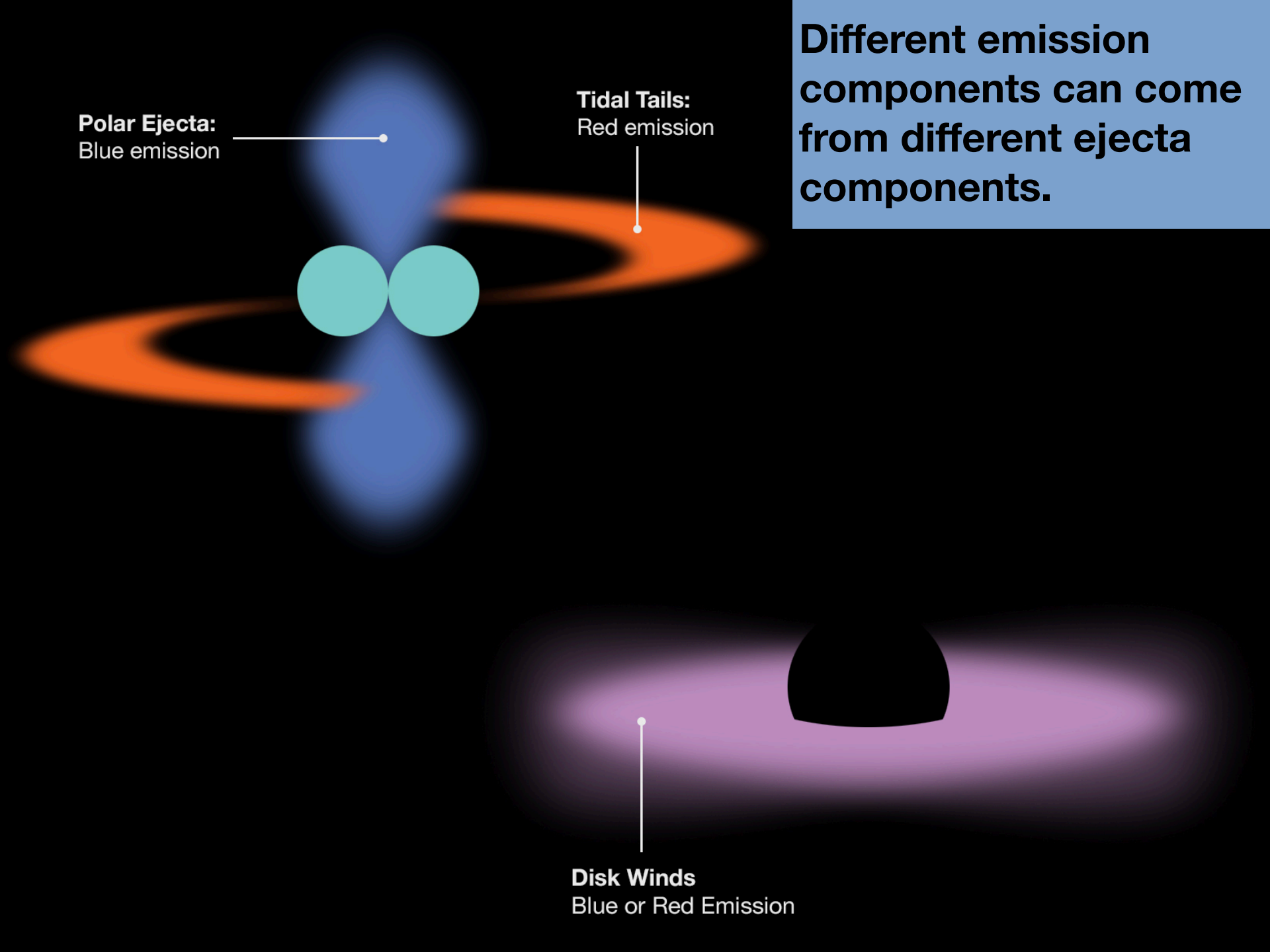
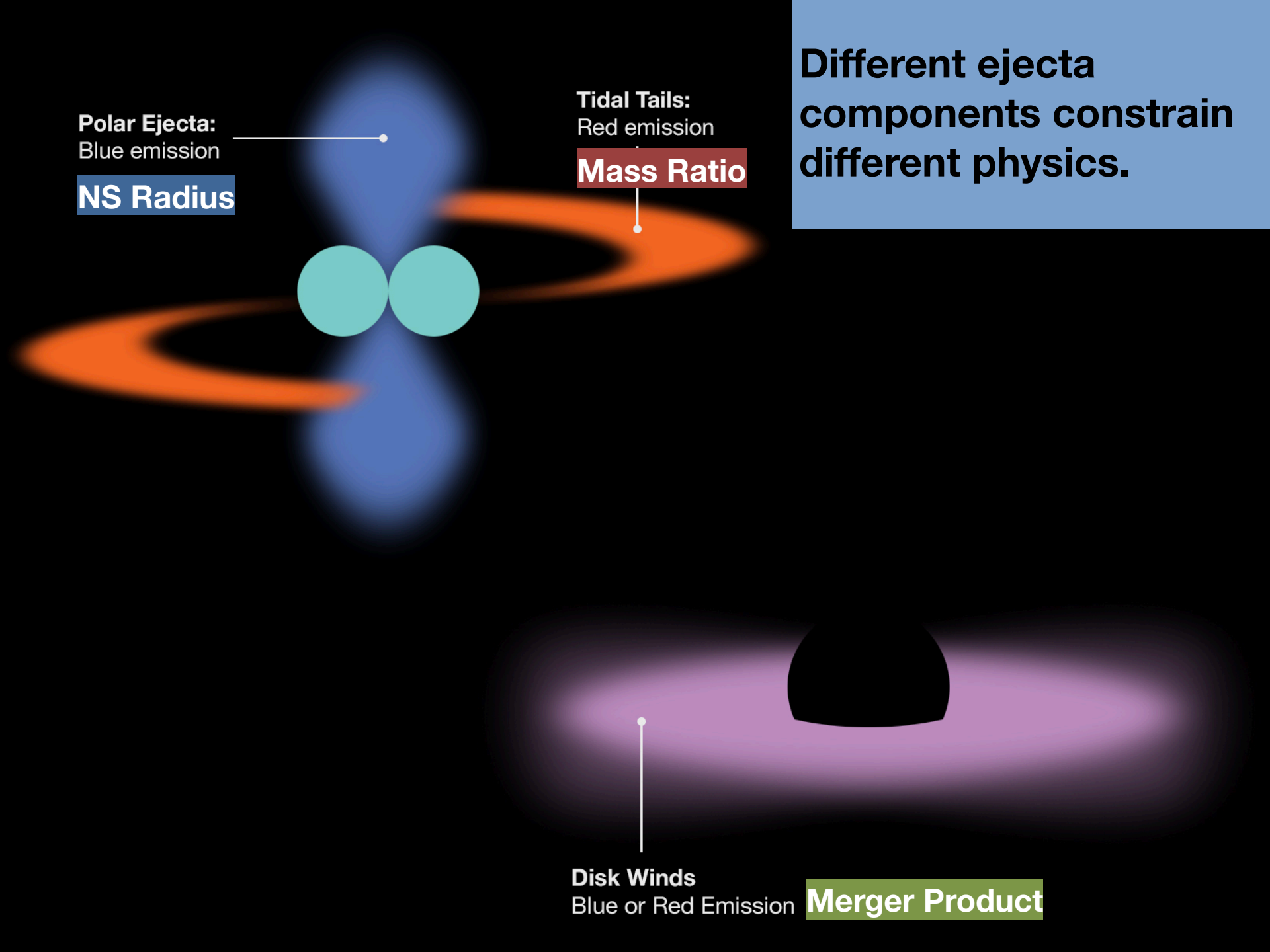
Different emission components can come from different ejecta components.



Different ejecta components constrain different physics.



Different Models for the Blue → Red Emission

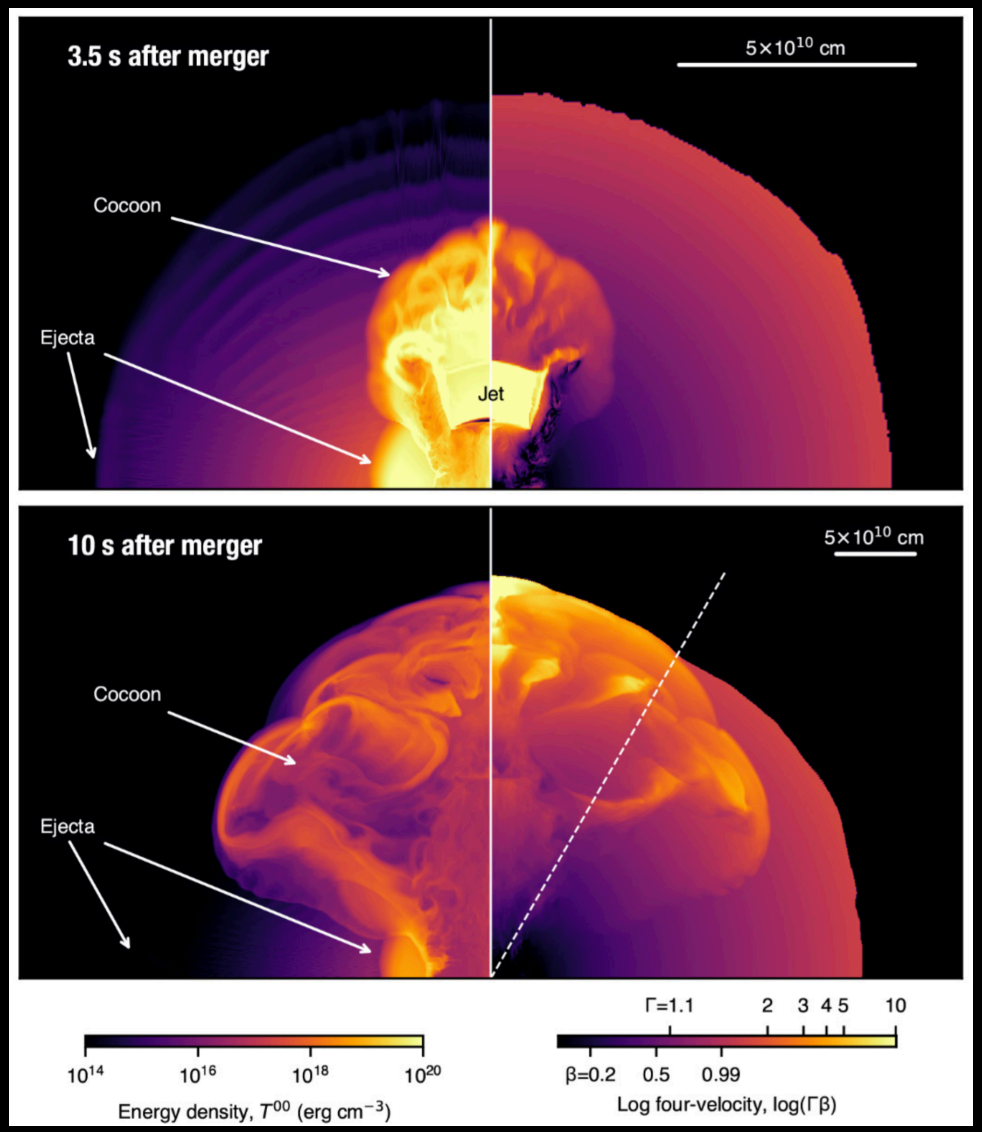
Multi-component radioactive decay
Villar et al. 2017

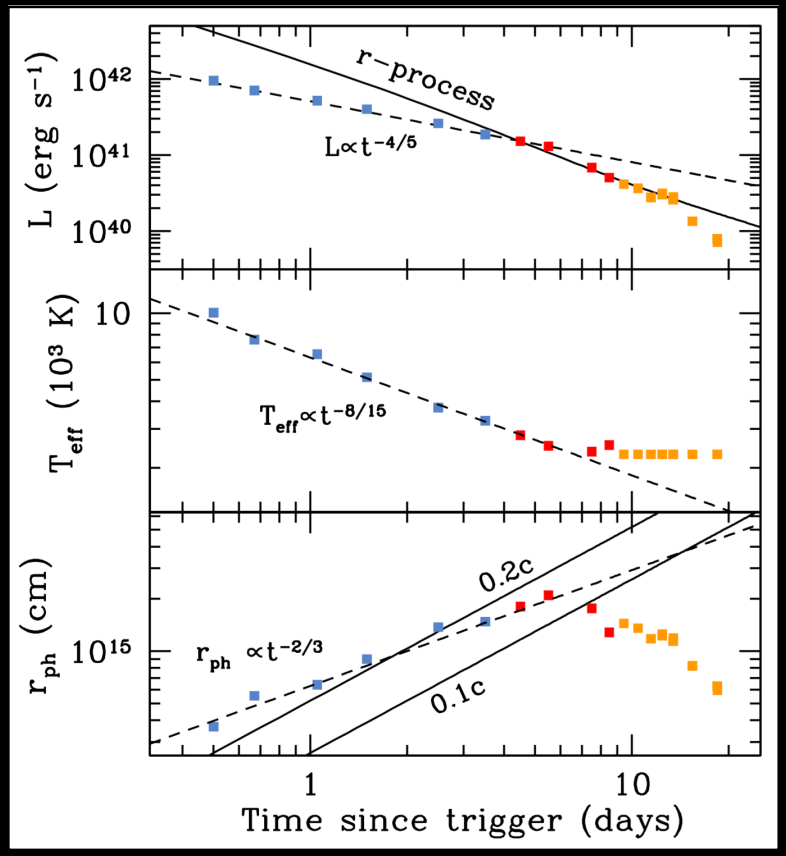
Single-component radioactive decay
(time-varying opacity) Waxman et al. 2017

Boosted relativistic ejecta
(early blue-emission) Kasliwal et al. 2017, see also Nakar & Piran 2017, Gottlieb et al. 2017

Shock cooling
(early blue-emission) Piro & Kollmeier 2017

Boosted / Shock Cooling = Evidence of Cocoon



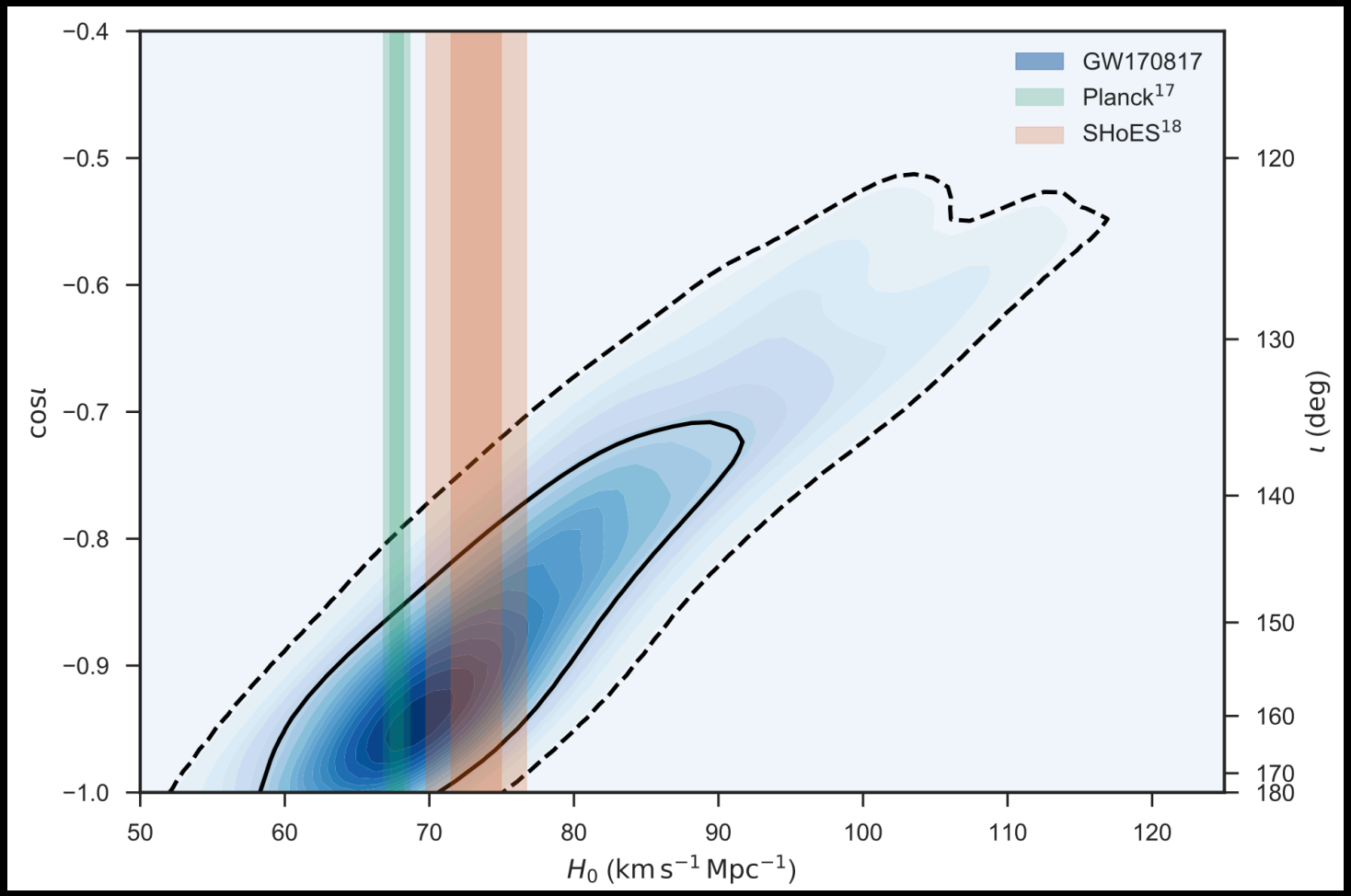


Kasliwal+ 2017

Piro & Kollmeier 2017

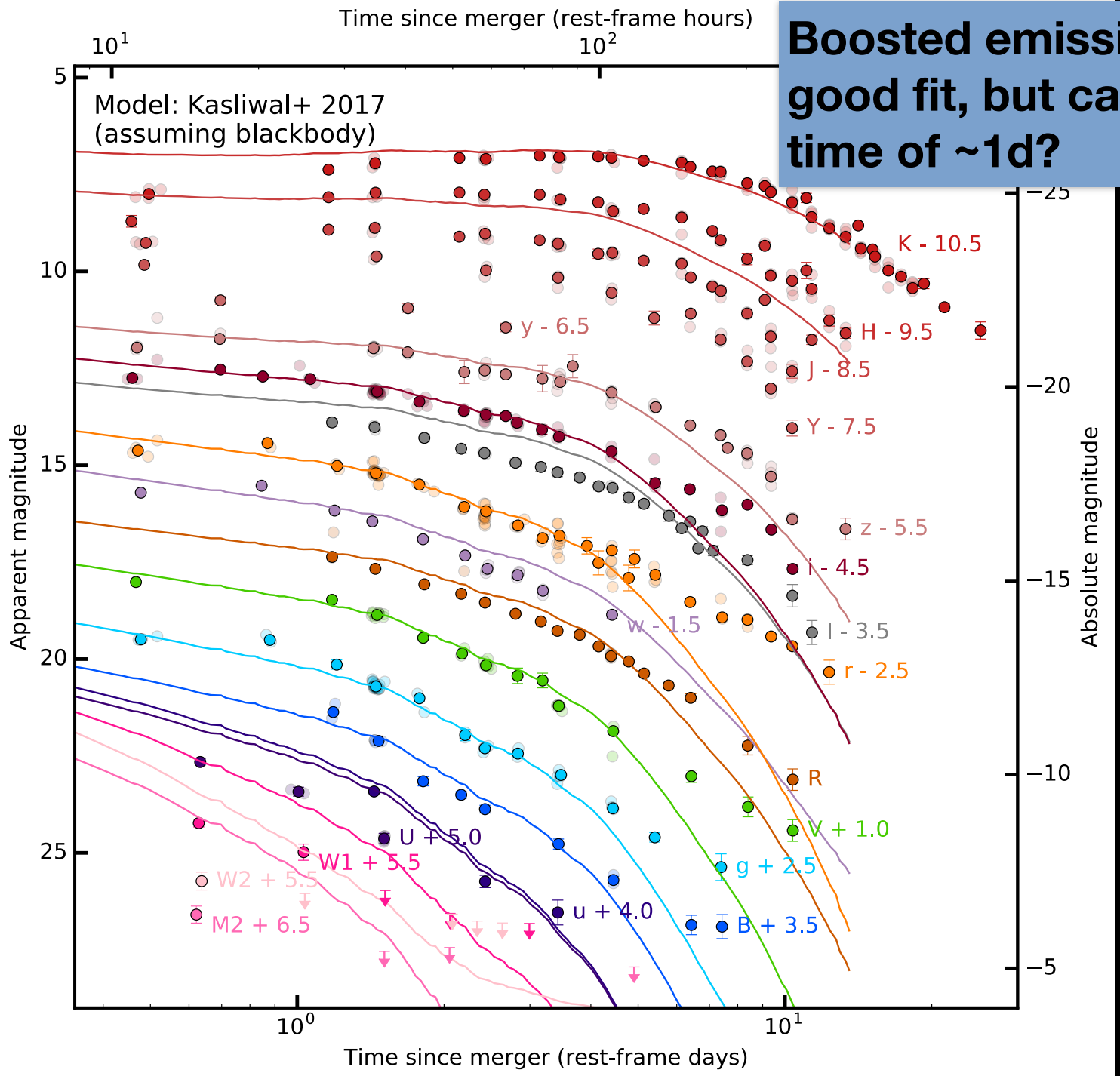
see also Nakar & Piran 2017, Gottlieb+ 2017

Polar Ejecta = Constraint on the Viewing Angle



LIGO & Virgo Collaborations et al. 2017, Nature

Boosted emission provides good fit, but can it have a rise time of ~1d?



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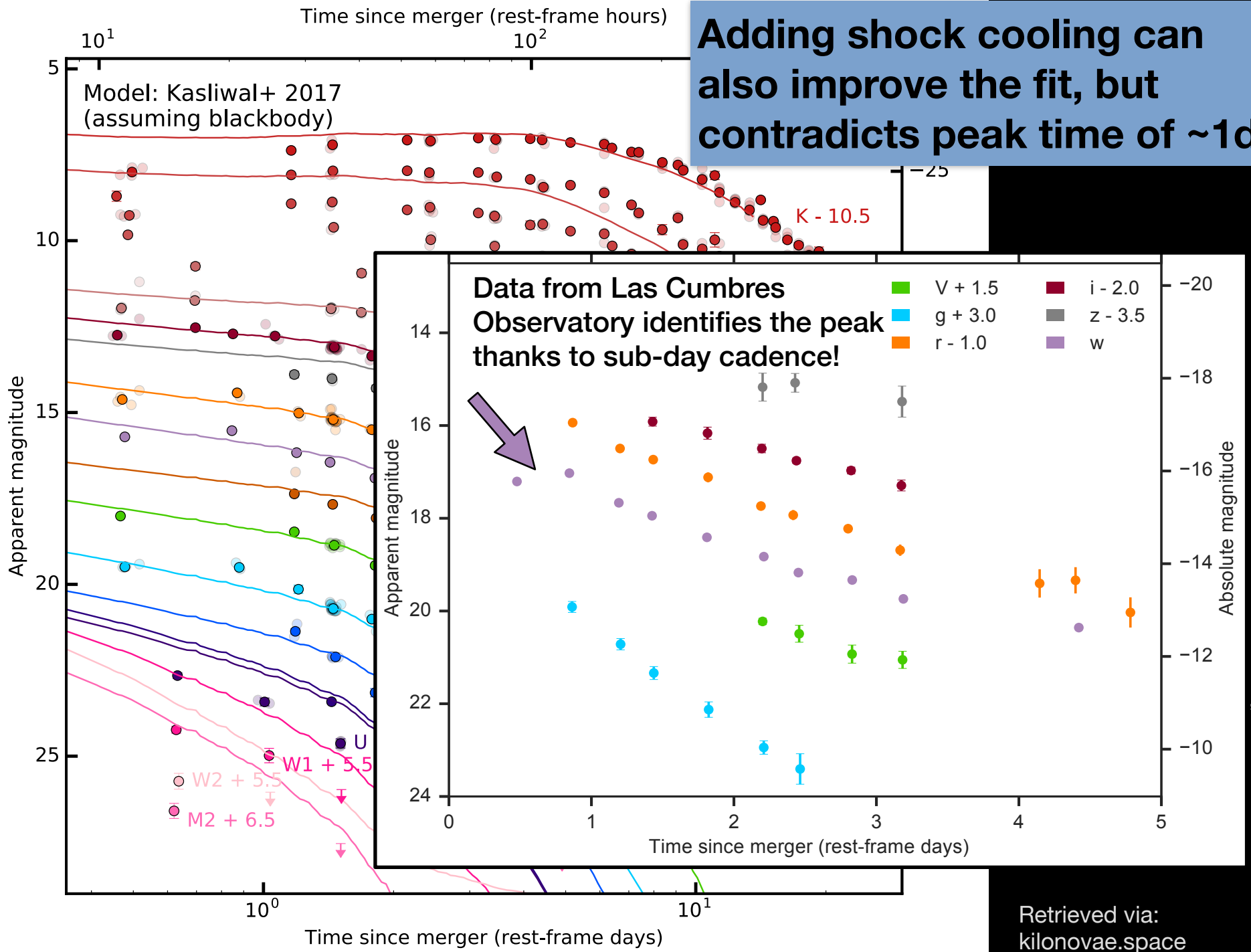
Adding shock cooling can also improve the fit, but contradicts peak time of ~1d.



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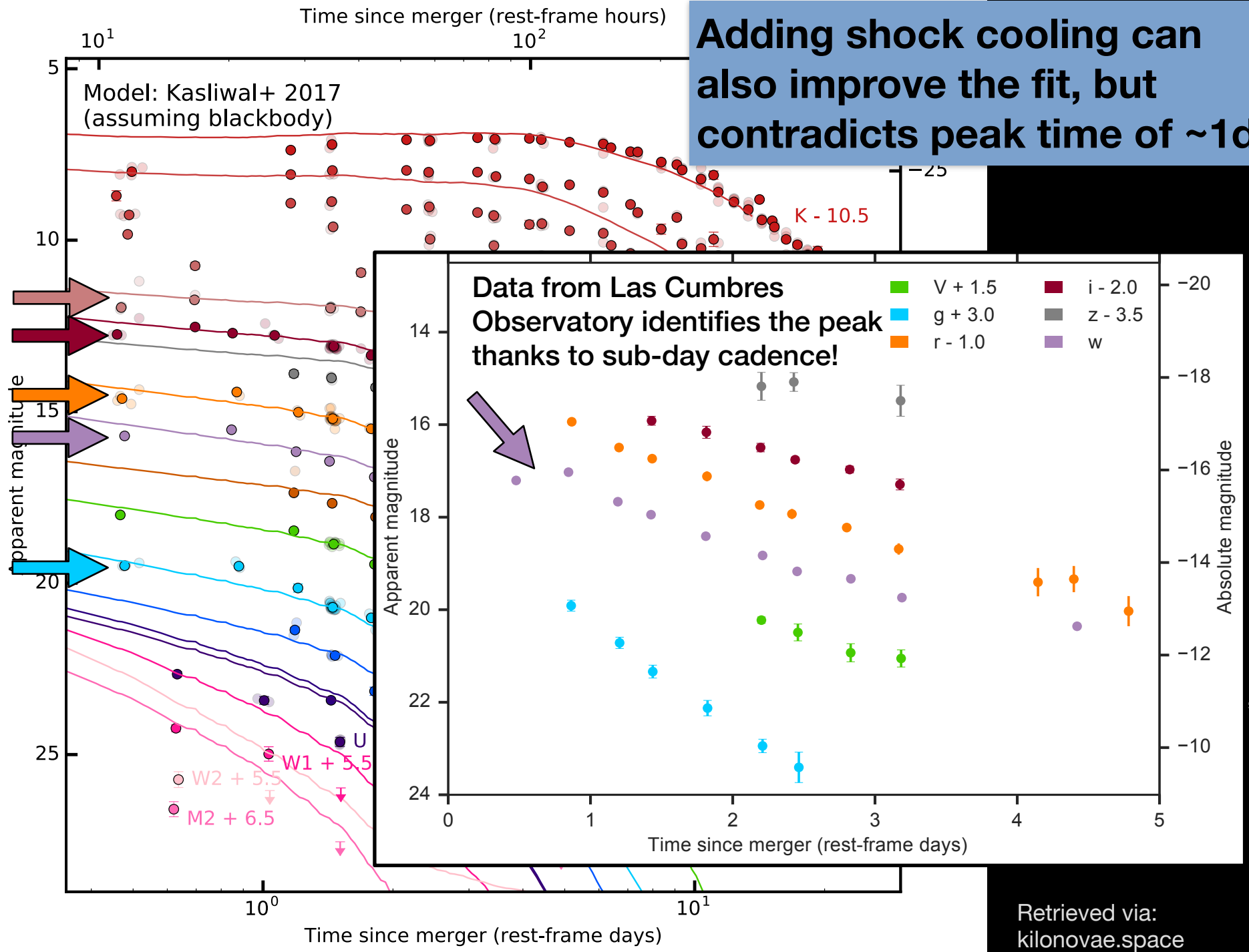

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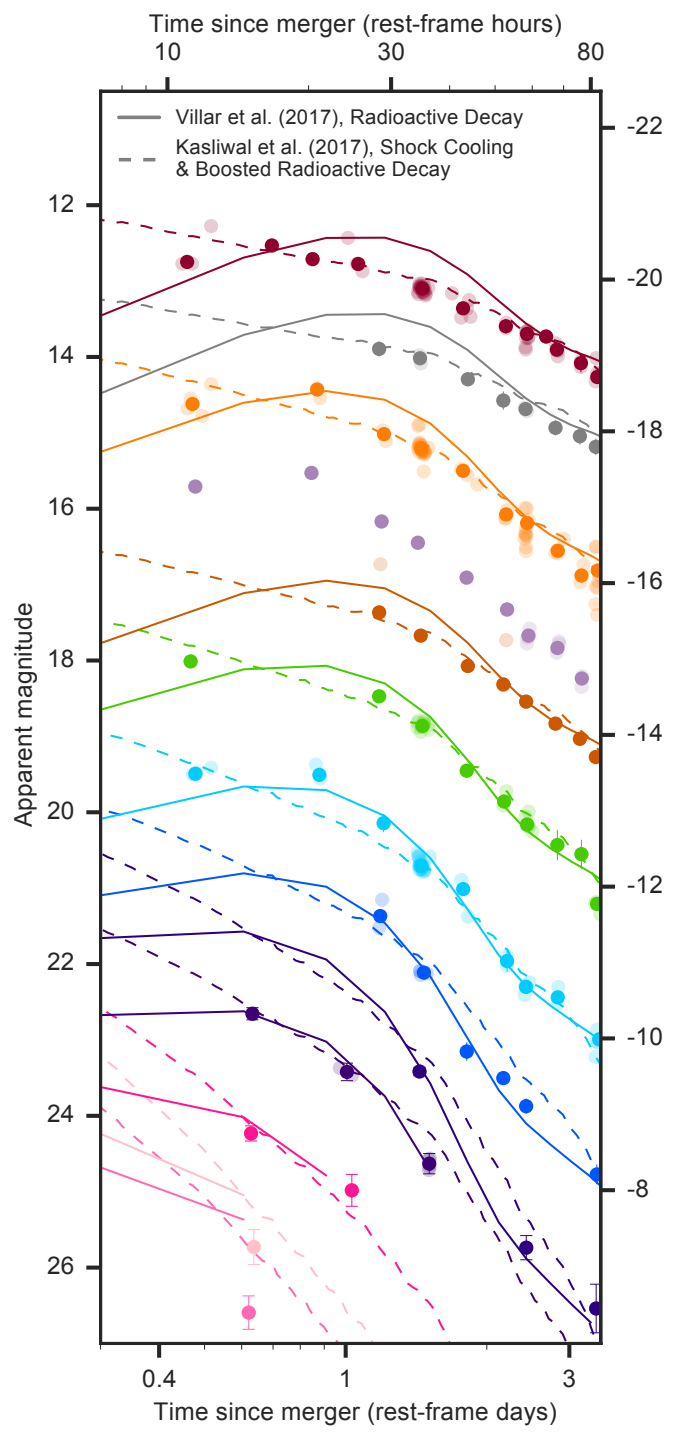
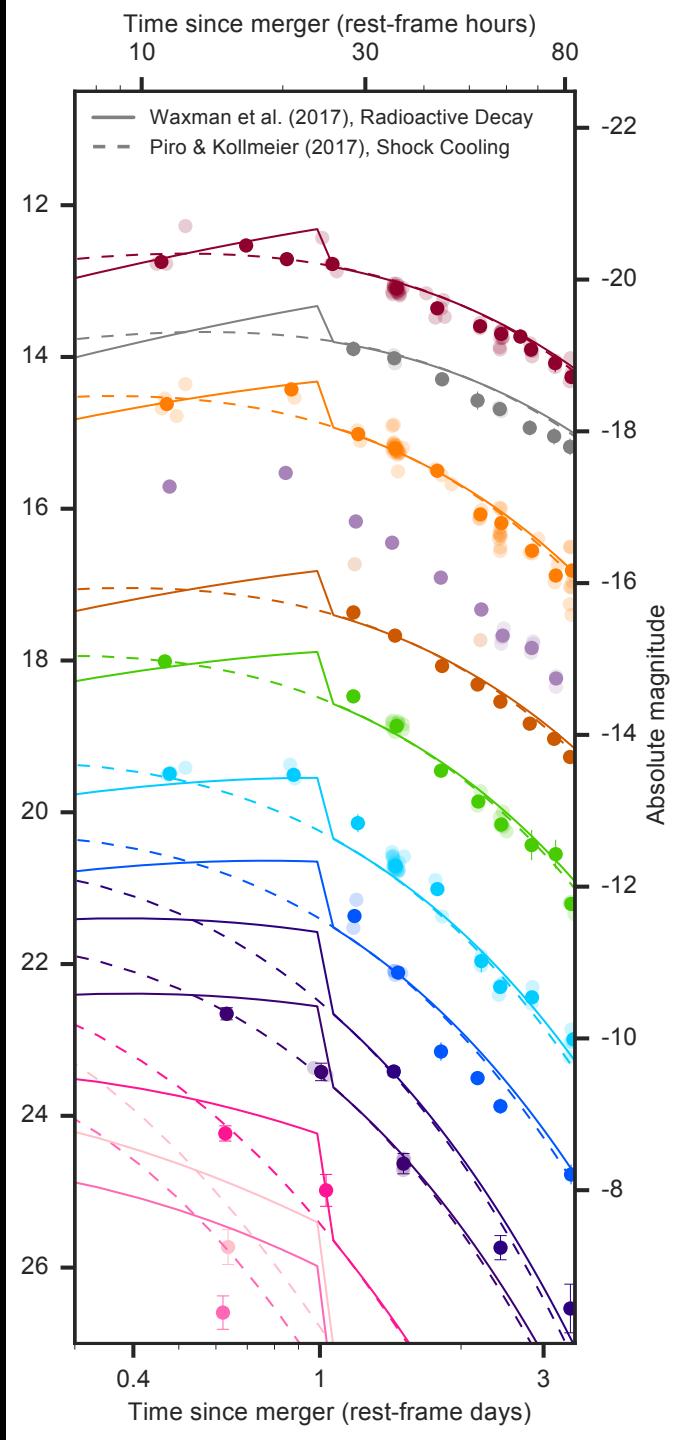

Time since merger (rest-frame hours)
10
30
80
Villar et al. (2017), Radioactive Decay
Kasliwal et al. (2017), Shock Cooling
& Boosted Radioactive Decay
Apparent magnitude
12
14
16
18
20
22
24
26
-22
-20
-18
-16
-14
-12
-10
-8
0.4
1
3
Time since merger (rest-frame days)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Waxman et al. (2017), Radioactive Decay
Piro & Kollmeier (2017), Shock Cooling
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16
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-20
-18
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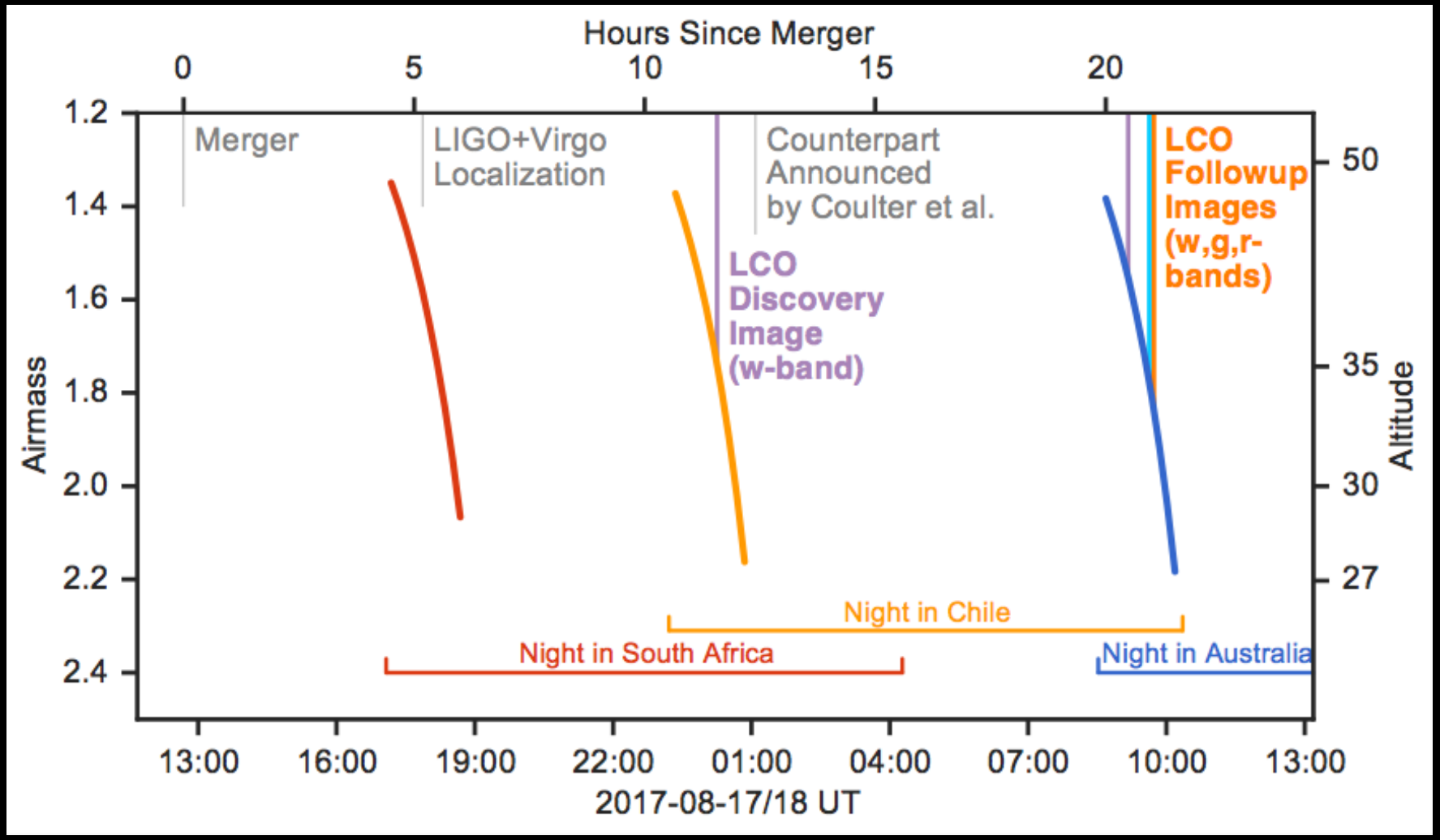
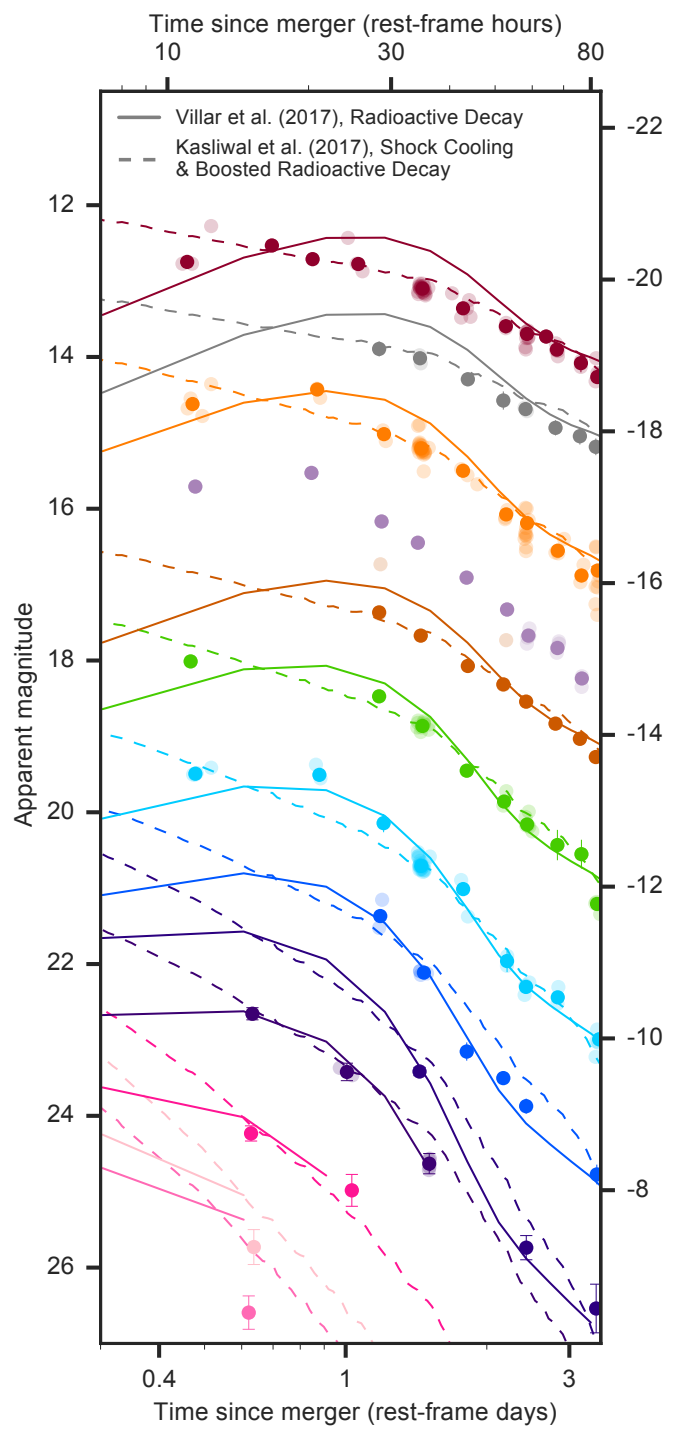
-12
-10
-8
Absolute magnitude
0.4
1
3
Time since merger (rest-frame days)

Arcavi
2018

Would Have Solved With LIGO Localization 1h Earlier



Arcavi et al. 2017a, Nature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Kasliwal et al. (2017), Shock Cooling
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-12
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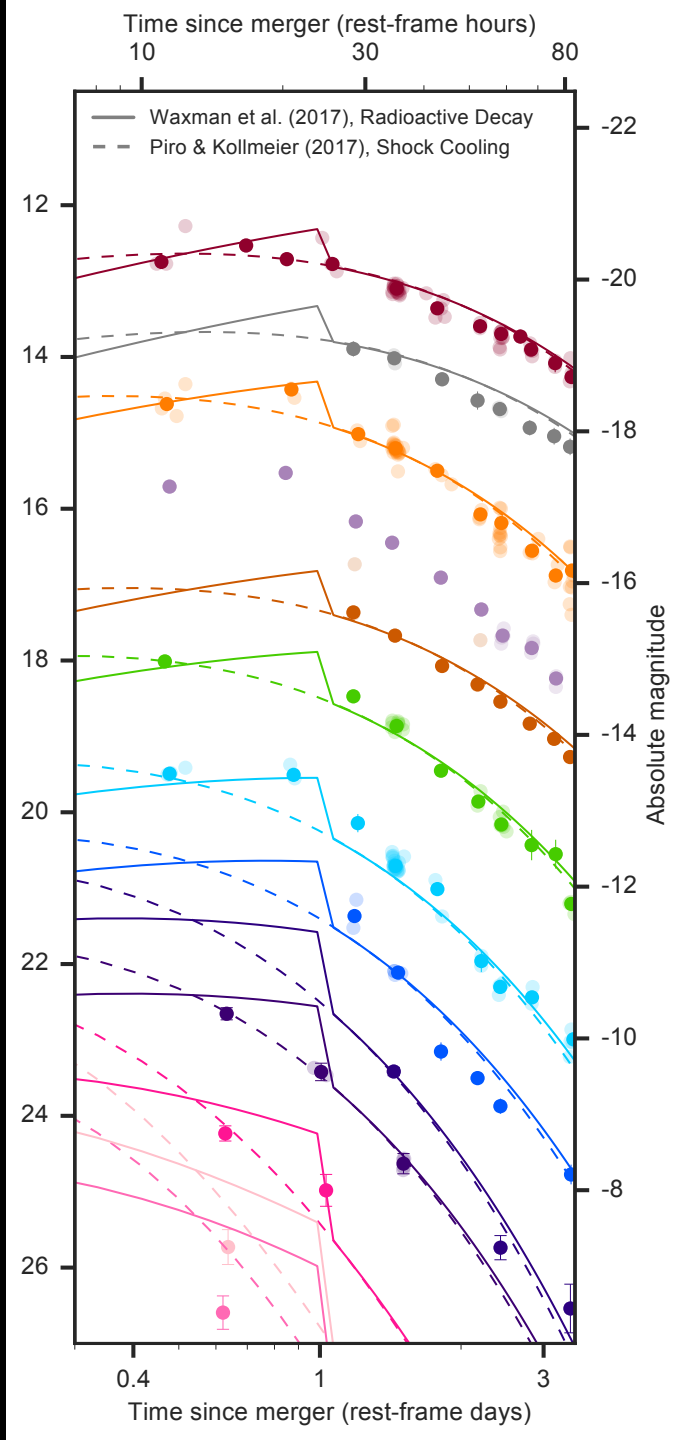
-8
0.4
1
3
Time since merger (rest-frame days)


Time since merger (rest-frame hours)
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Waxman et al. (2017), Radioactive Decay
Piro & Kollmeier (2017), Shock Cooling
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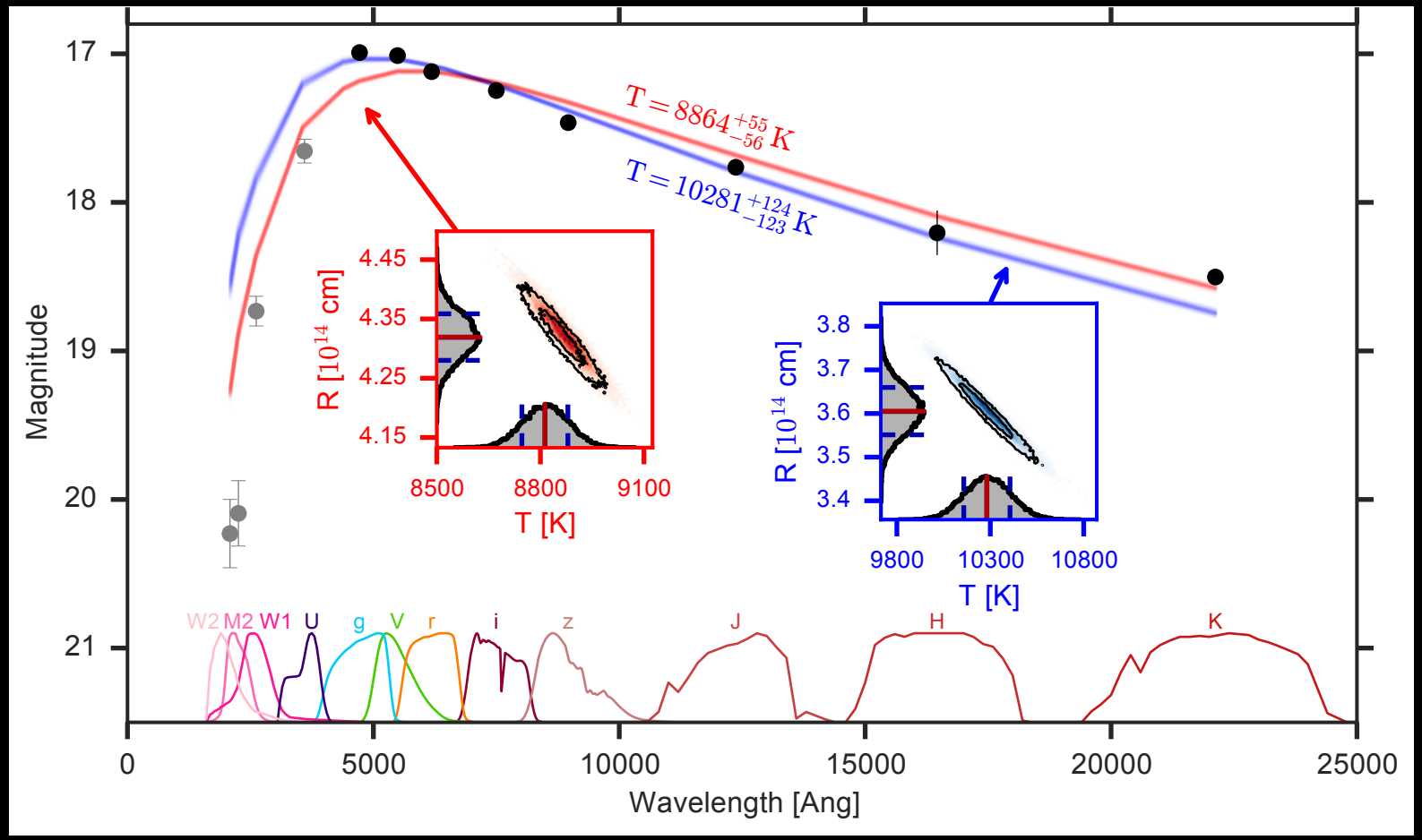
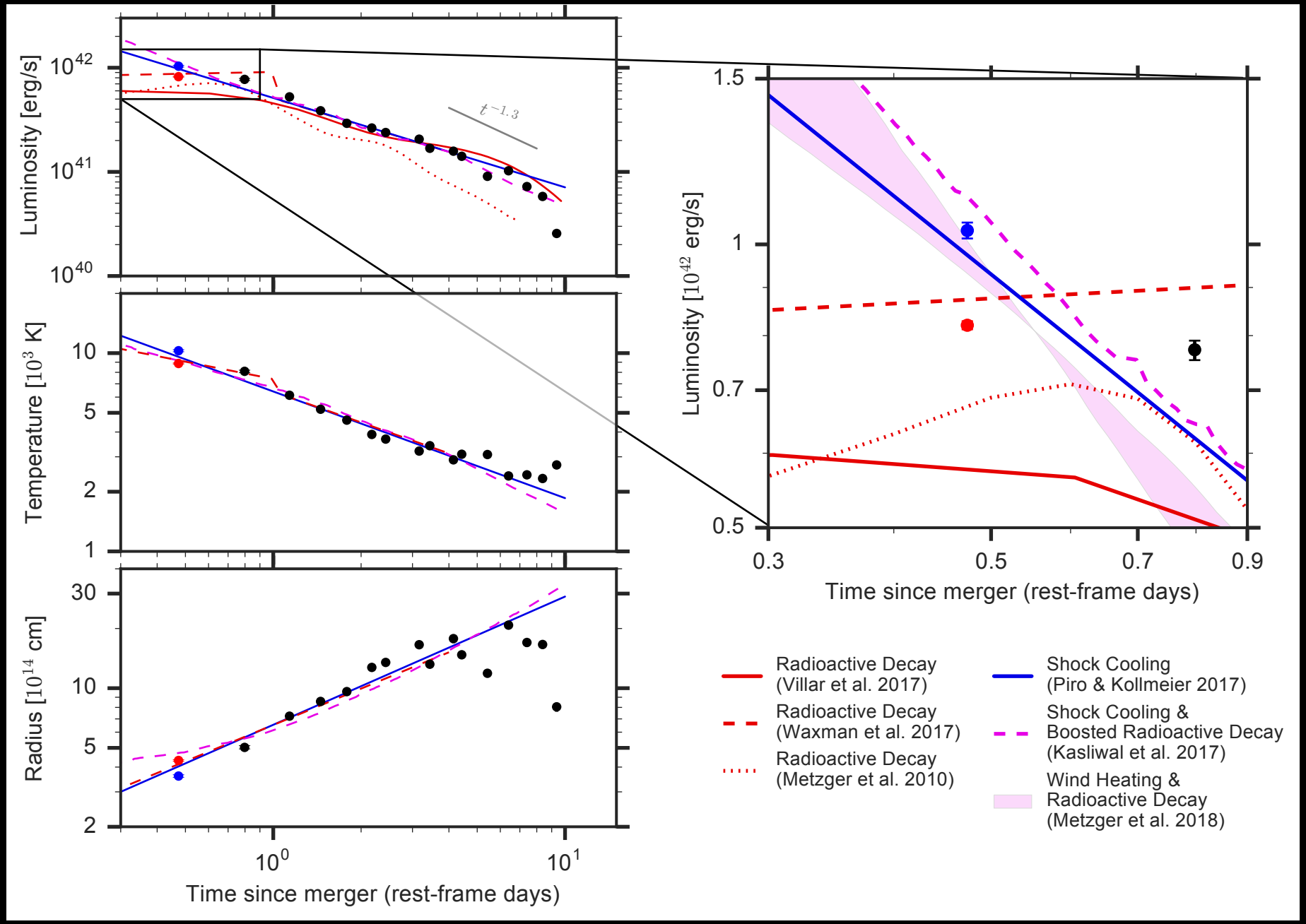
-22
-20
-18
-16
-14
-12
-10
-8
Absolute magnitude
0.4
1
3
Time since merger (rest-frame days)

Arcavi
2018

UV - Optical Discovery Time Difference Was Critical

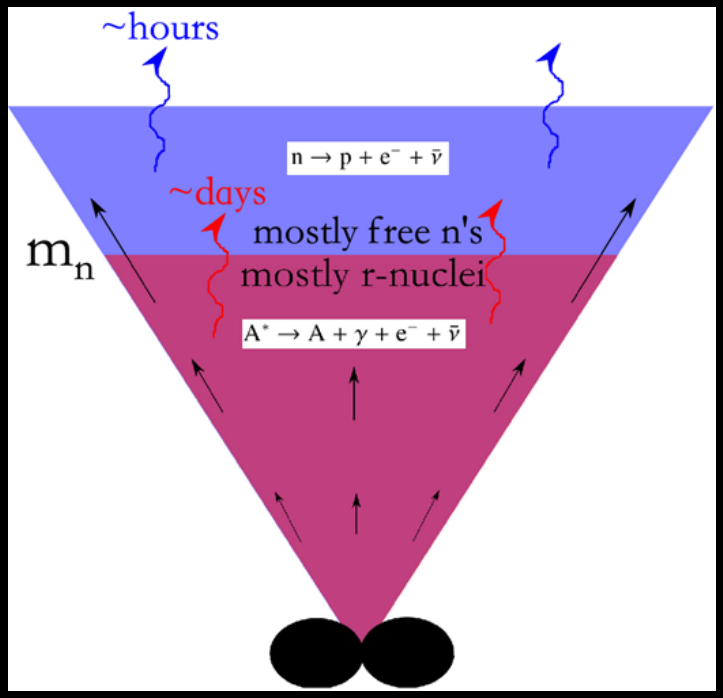


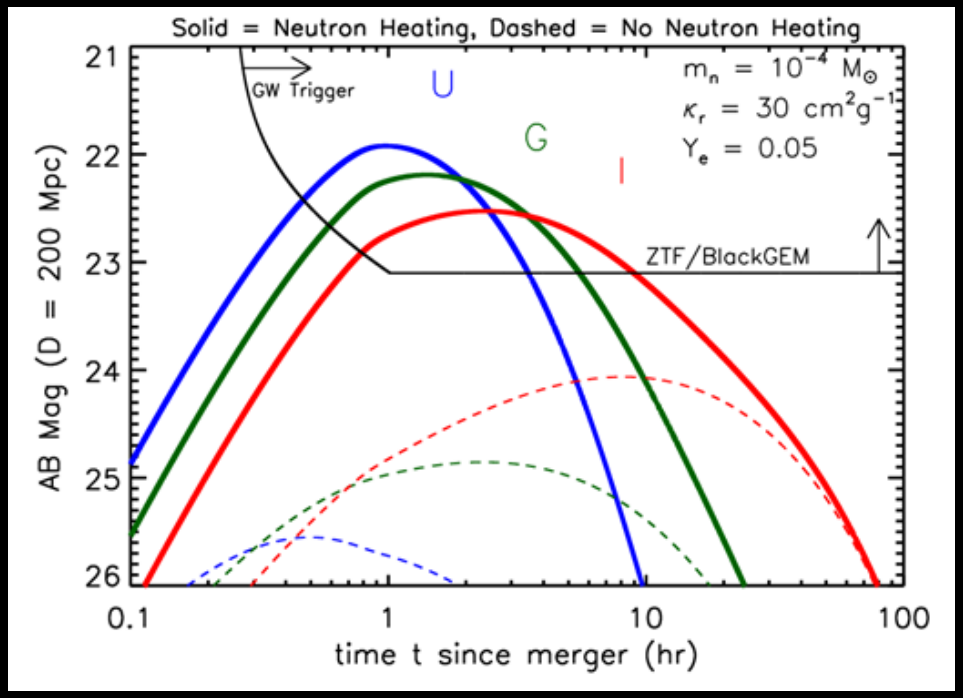
Arcavi 2018, ApJL, accepted arXiv: 1802.02164


Luminosity [erg/s]
10^{42}
10^{41}
10^{40}
$t^{-1.3}$
Temperature [10^3 K]
10
5
2
1
Radius [10^{14} cm]
30
10
5
2
10^0
10^1
Time since merger (rest-frame days)
Luminosity [10^{42} erg/s]
1.5
1
0.7
0.5
0.3
0.5
0.7
0.9
Time since merger (rest-frame days)
Radioactive Decay (Villar et al. 2017)
Radioactive Decay (Waxman et al. 2017)
Radioactive Decay (Metzger et al. 2010)
Shock Cooling (Piro & Kollmeier 2017)
Shock Cooling & Boosted Radioactive Decay (Kasliwal et al. 2017)
Wind Heating & Radioactive Decay (Metzger et al. 2018)

Arcavi 2018

Predicted One-Hour Time Scale Blue Emission





Metzger et al. 2015

Early Optical-UV Kilonova Observations Are Crucial

What is the source of the early blue emission? Radioactive decay from low opacity ejecta, radioactive decay from boosted high velocity ejecta, shock cooling, or combinations thereof?

This is important: Various ejecta components potentially constrain NS EOS, nucleosynthesis, jet launching, cocoon forming, inclination angle (→ Hubble Constant).

Early data critical! Distinguishing between emission models requires optical-UV observations starting **few hour/s** after merger (10 hours is too late) with **sub-day** cadence.

Technical Topics for Discussion

Are Fermi localizations going to be in the same format as LVC ones? Our search was delayed in order to adjust our pipeline to use the GRB170817 Fermi localization.

Are there going to be joint Fermi-LVC localization maps? In case one GW detector is offline, combining maps could significantly narrow the search region.

Is there going to be an API to report and query EM search locations? A first step for coordinating followup and avoiding duplications.