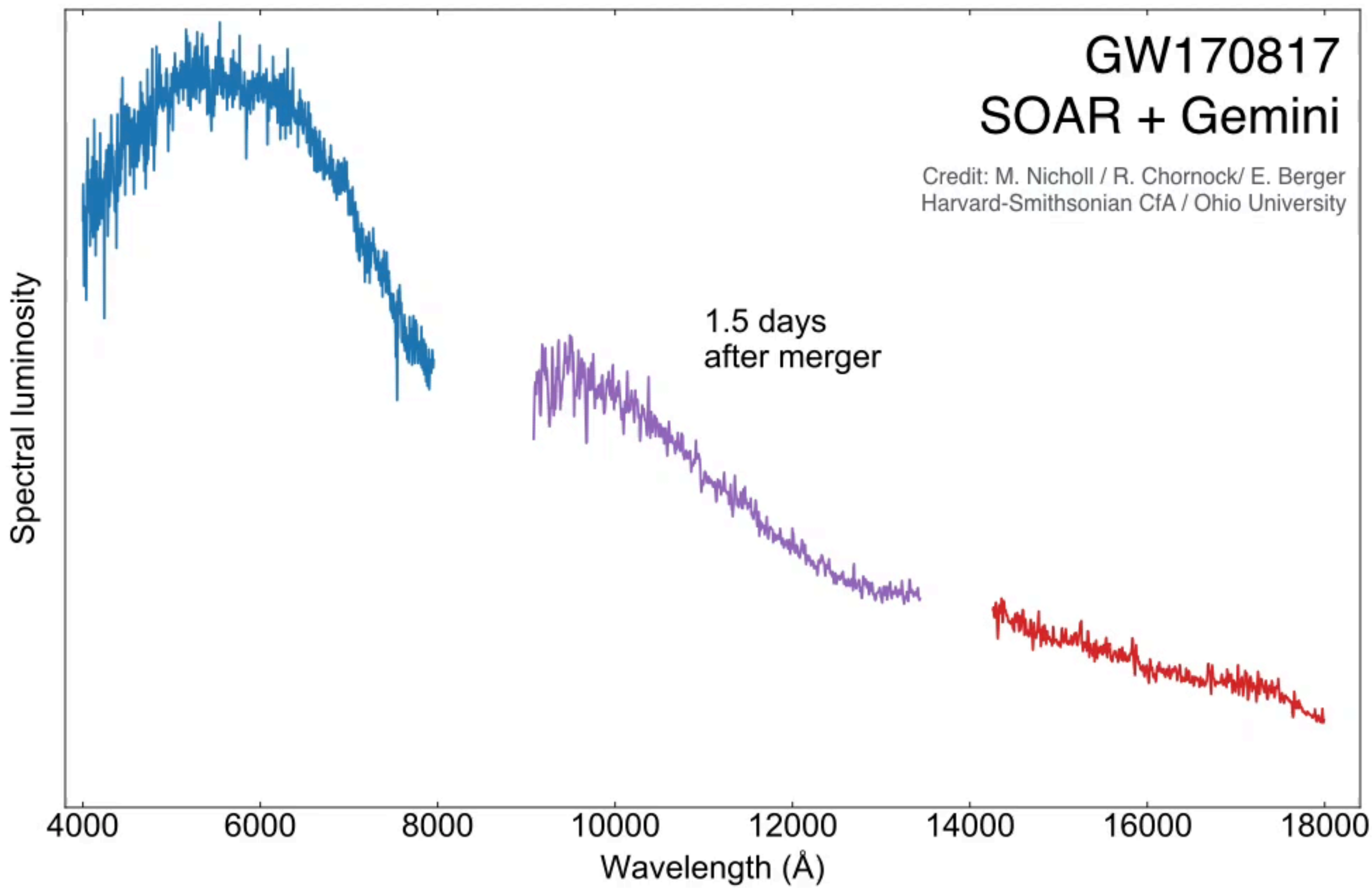
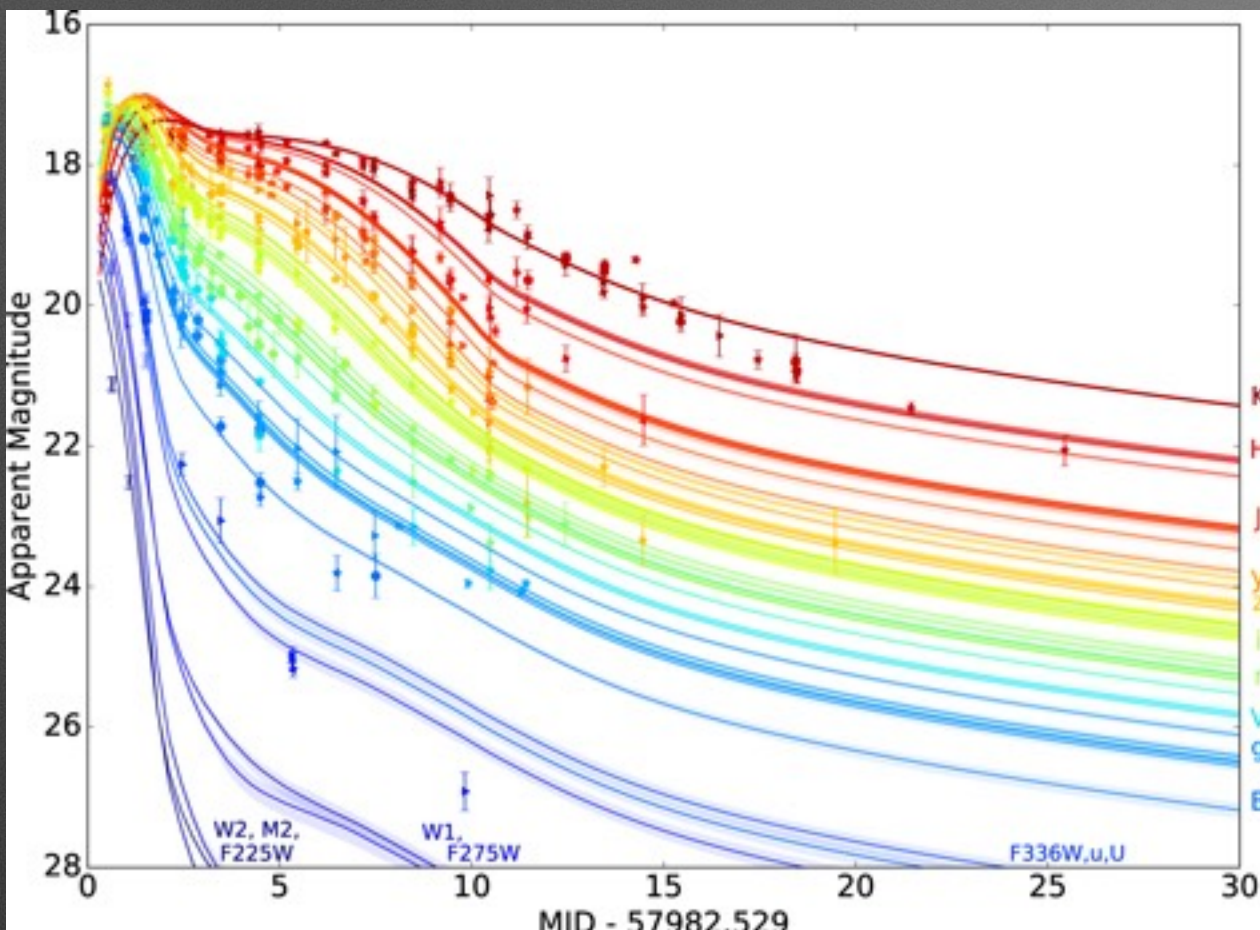
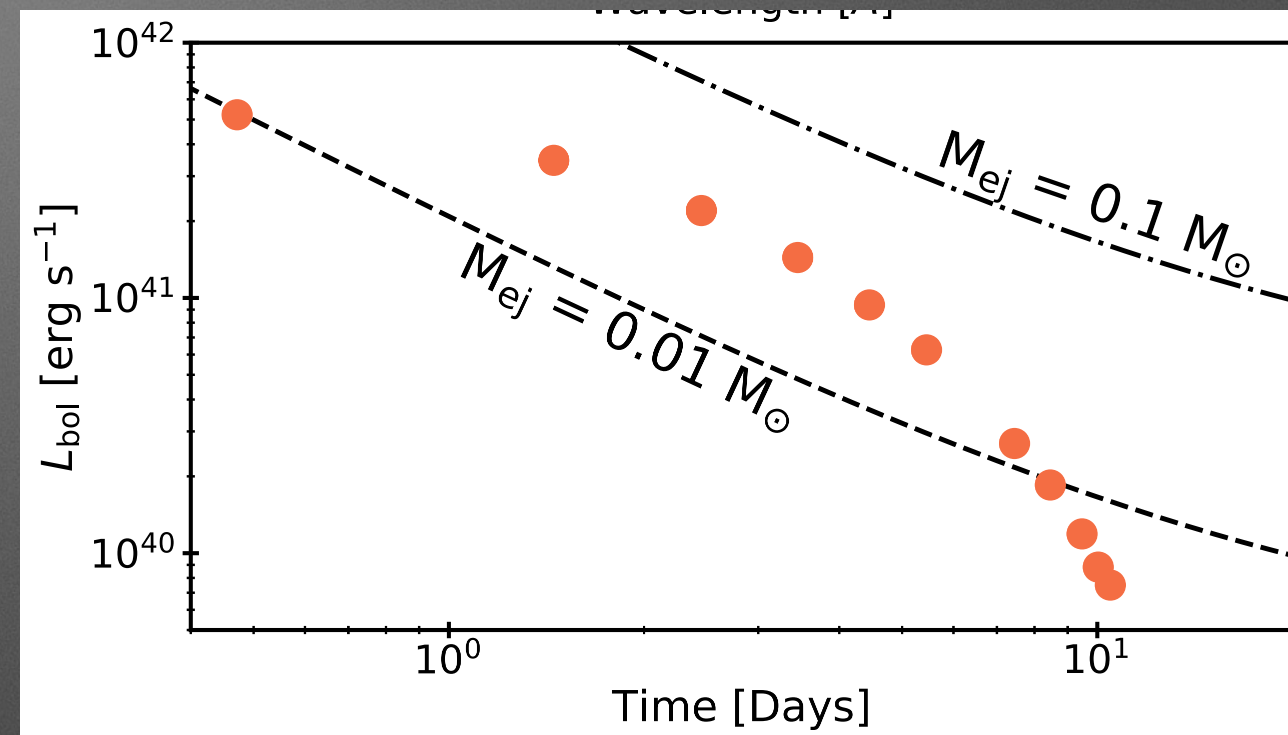

GW170817
SOAR + Gemini
Credit: M. Nicholl / R. Chornock/ E. Berger
Harvard-Smithsonian CfA / Ohio University
1.5 days
after merger
Spectral luminosity
4000
6000
8000
10000
12000
14000
16000
18000
Wavelength (Å)

Basic Observations of GW170817



Villar et al. 2017



Cowperthwaite et al. 2017

- Very fast fading in blue, slower in near-IR
- Color temperature of ~2500K after a week
- Luminosity/timescale consistent with ~few×10^{-2} $M_\odot$ of *r*-process ejecta

Neutron star merger ejecta and kilonova components

final few orbits:

strong GW source

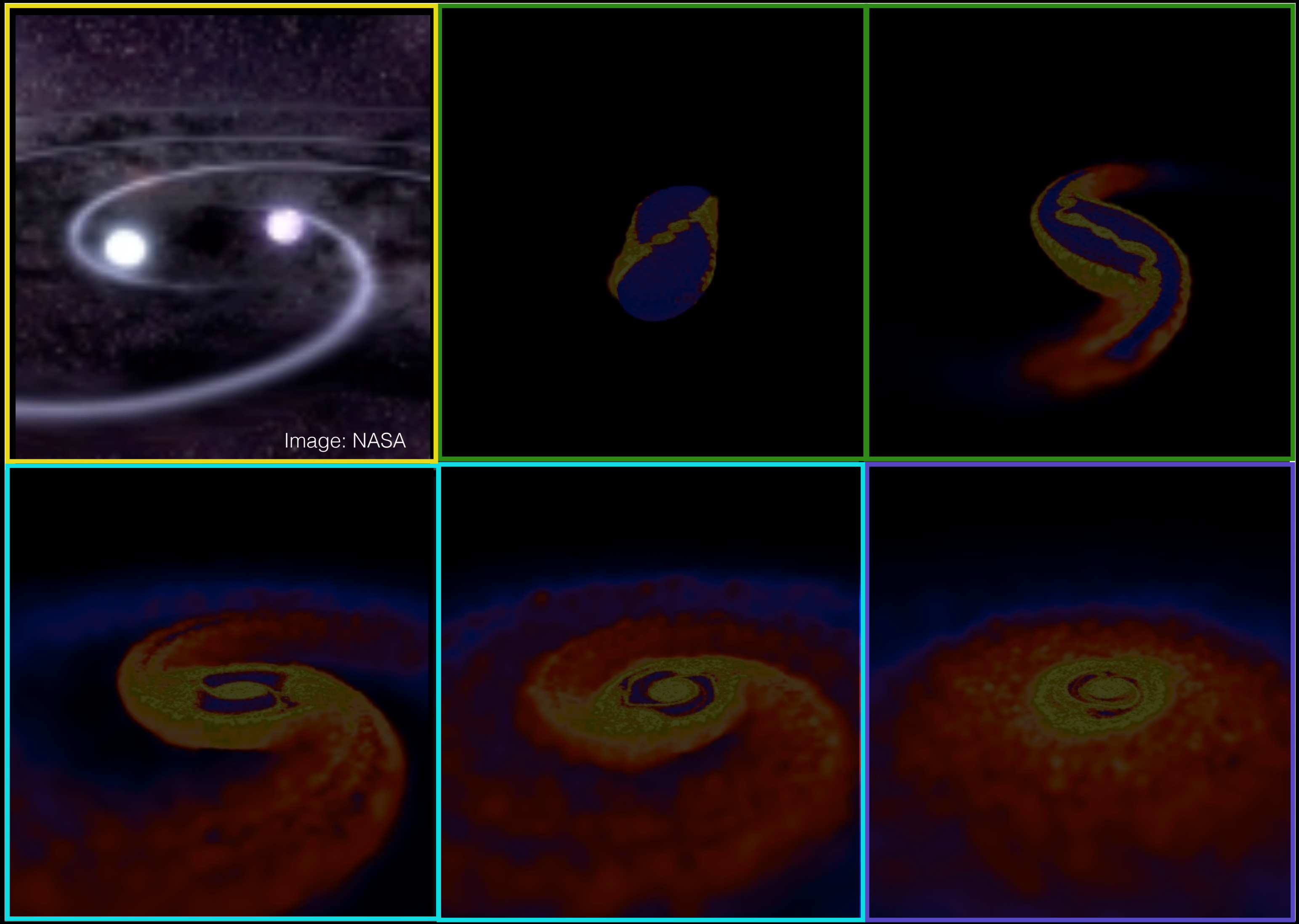


Image credit: Daniel Price (U/Exeter) and Stephan Rosswog (Int. U/Bremen)

Neutron star merger ejecta and kilonova components

final few orbits:
strong GW source

merger: neutron star is partially disrupted, central remnant forms

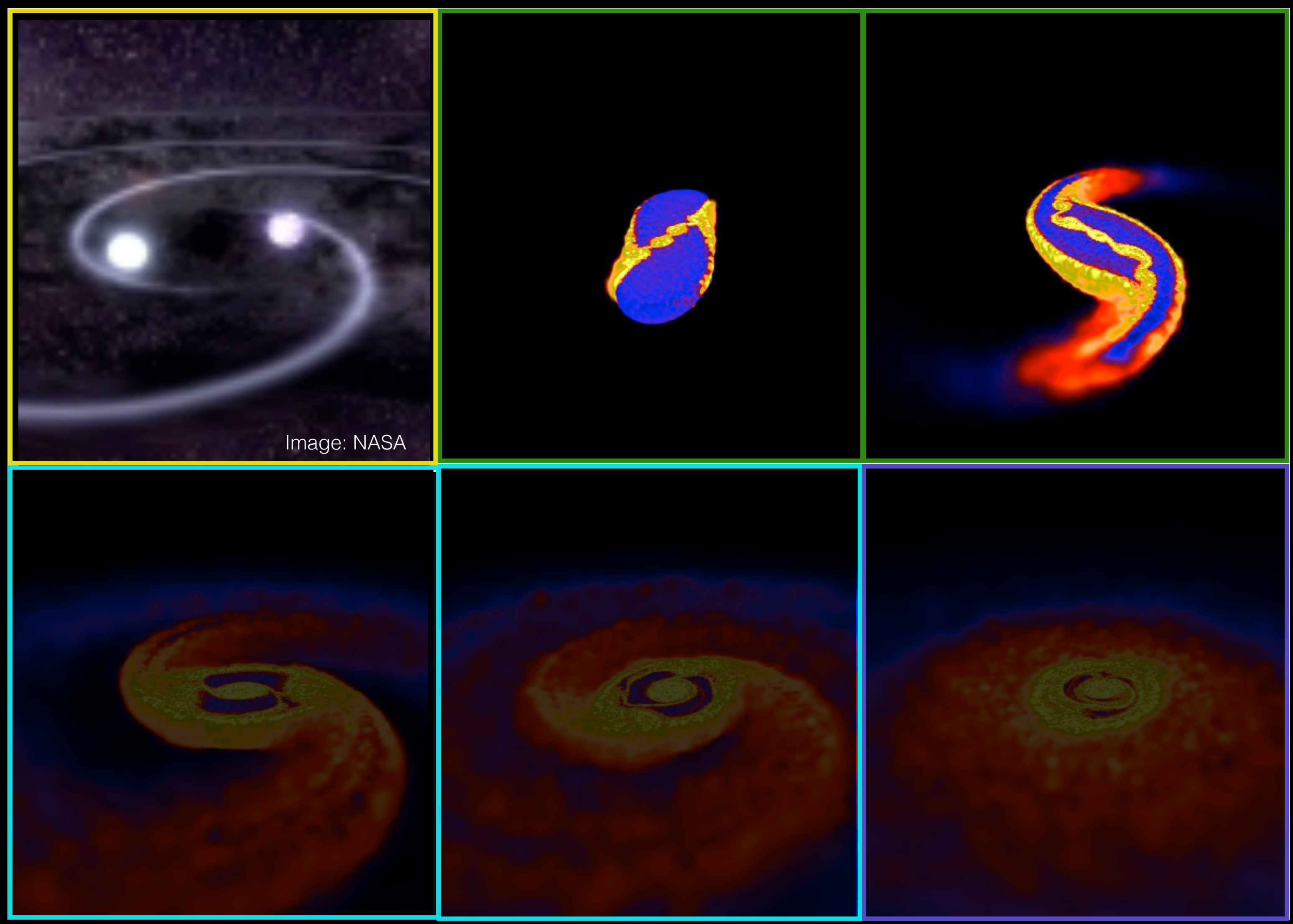
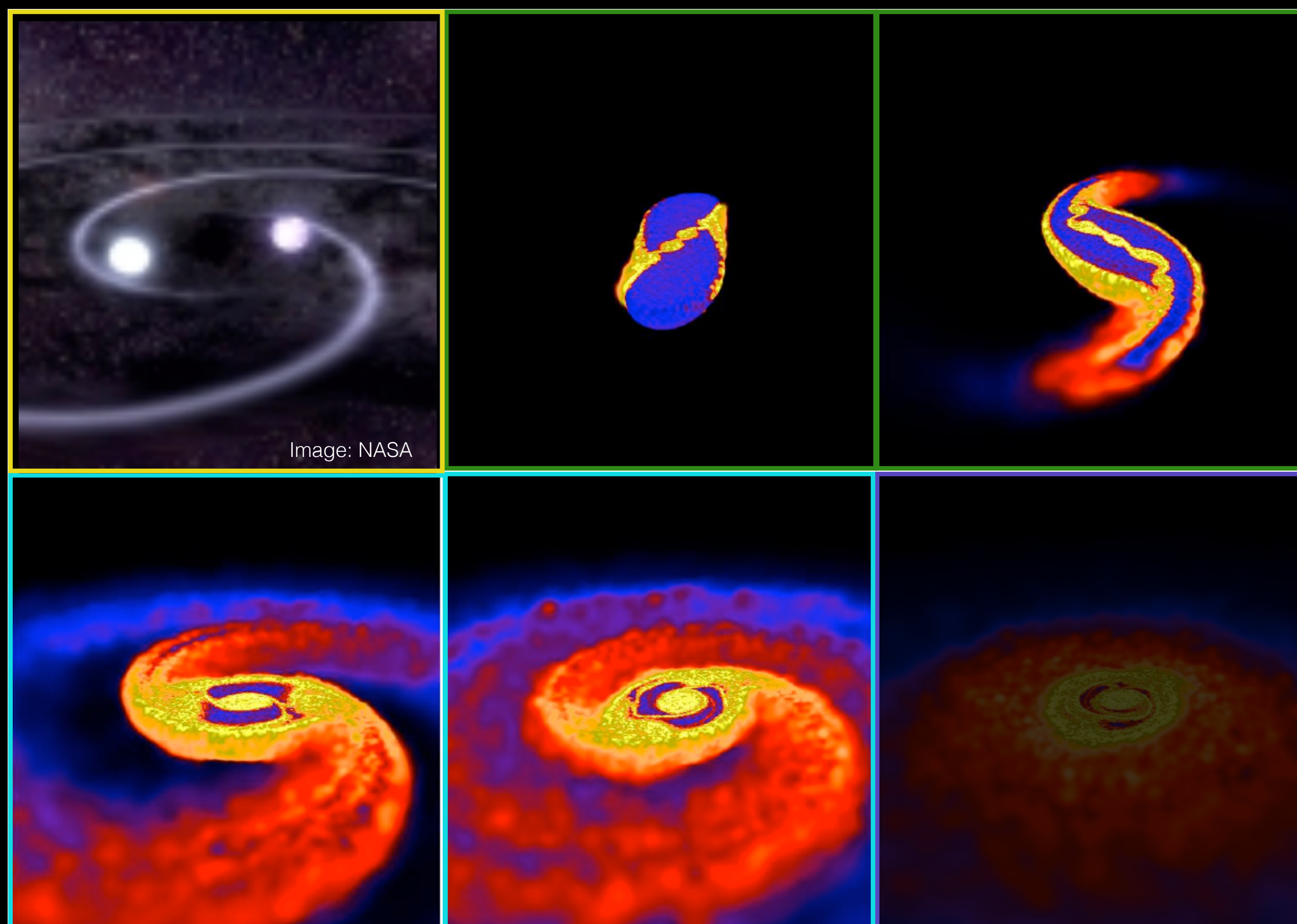


Image credit: Daniel Price (U/Exeter) and Stephan Rosswog (Int. U/Bremen)

Neutron star merger ejecta and kilonova components

final few orbits: strong GW source

merger: neutron star is partially disrupted, central remnant forms



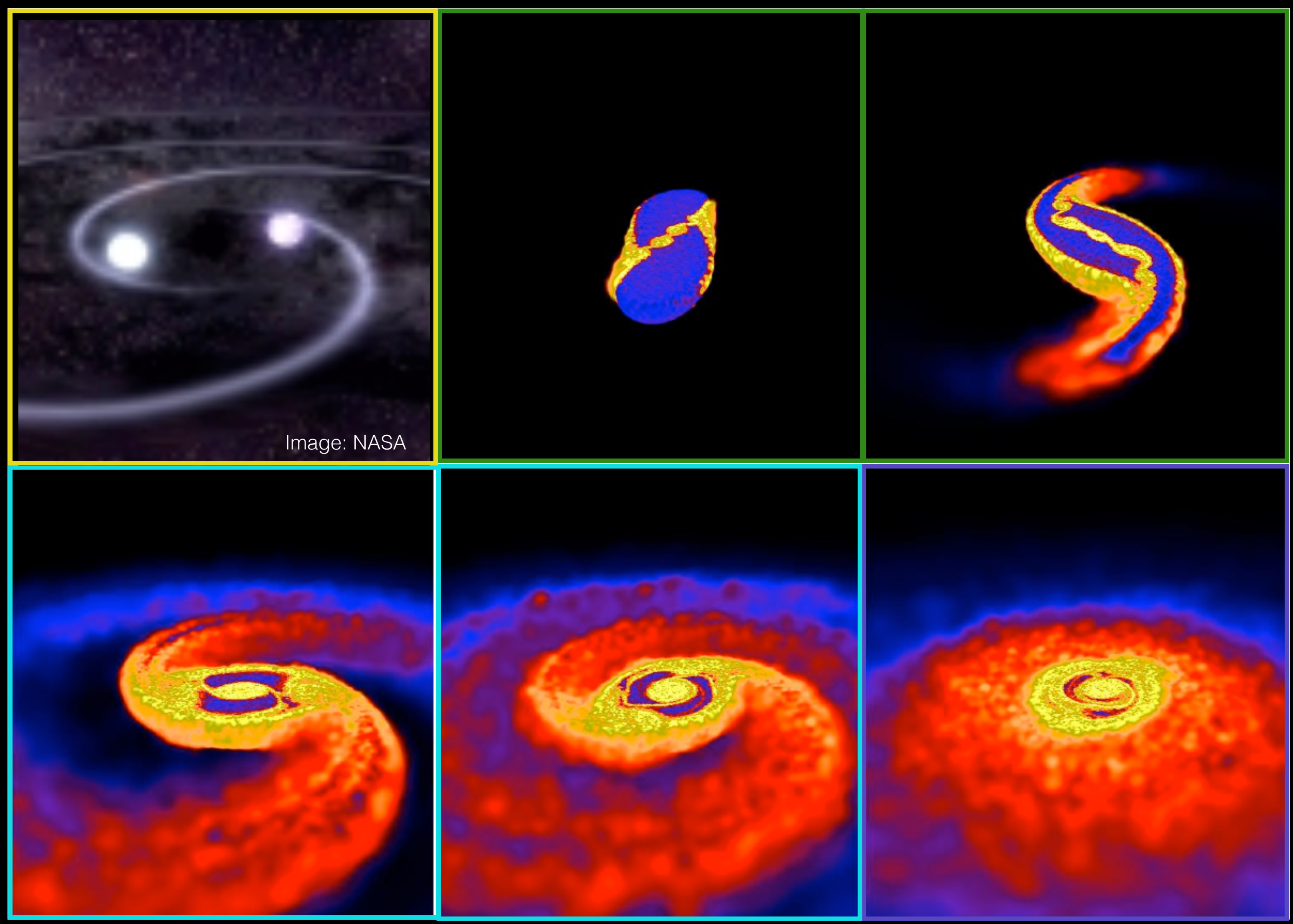
ejecta: some material escapes; some is bound

Image credit: Daniel Price (U/Exeter) and Stephan Rosswog (Int. U/Bremen)

Neutron star merger ejecta and kilonova components

final few orbits: strong GW source

merger: neutron star is partially disrupted, central remnant forms



ejecta: some material escapes; some is bound

final: a central NS or BH, an accretion disk, unbound ejecta

Image credit: Daniel Price (U/Exeter) and Stephan Rosswog (Int. U/Bremen)

Value-add from EM Counterparts

1. Cosmology

Host-galaxy identification → redshift → calculation of H_0
(host galaxies can also constrain stellar binary evolution)

2. Origin of *r*-process elements

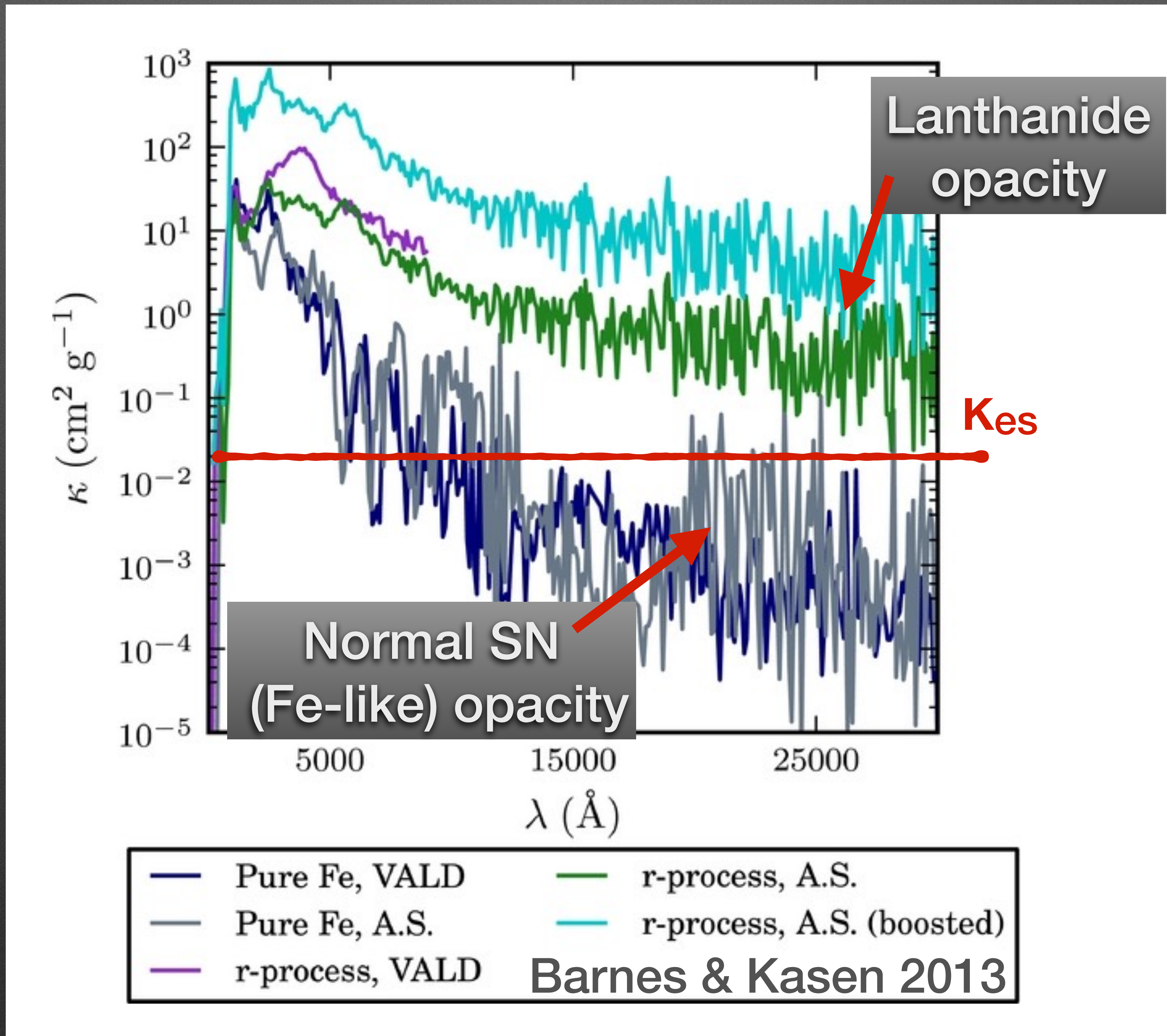
Only electromagnetic emission can diagnose nucleosynthesis

3. NS Equation of State

M_{ej}, v_{ej}, and composition depend on binary parameters and EOS

- NS radius → prevalence of different ejecta components
- MHNS lifetime → nucleosynthesis in the post-merger disk

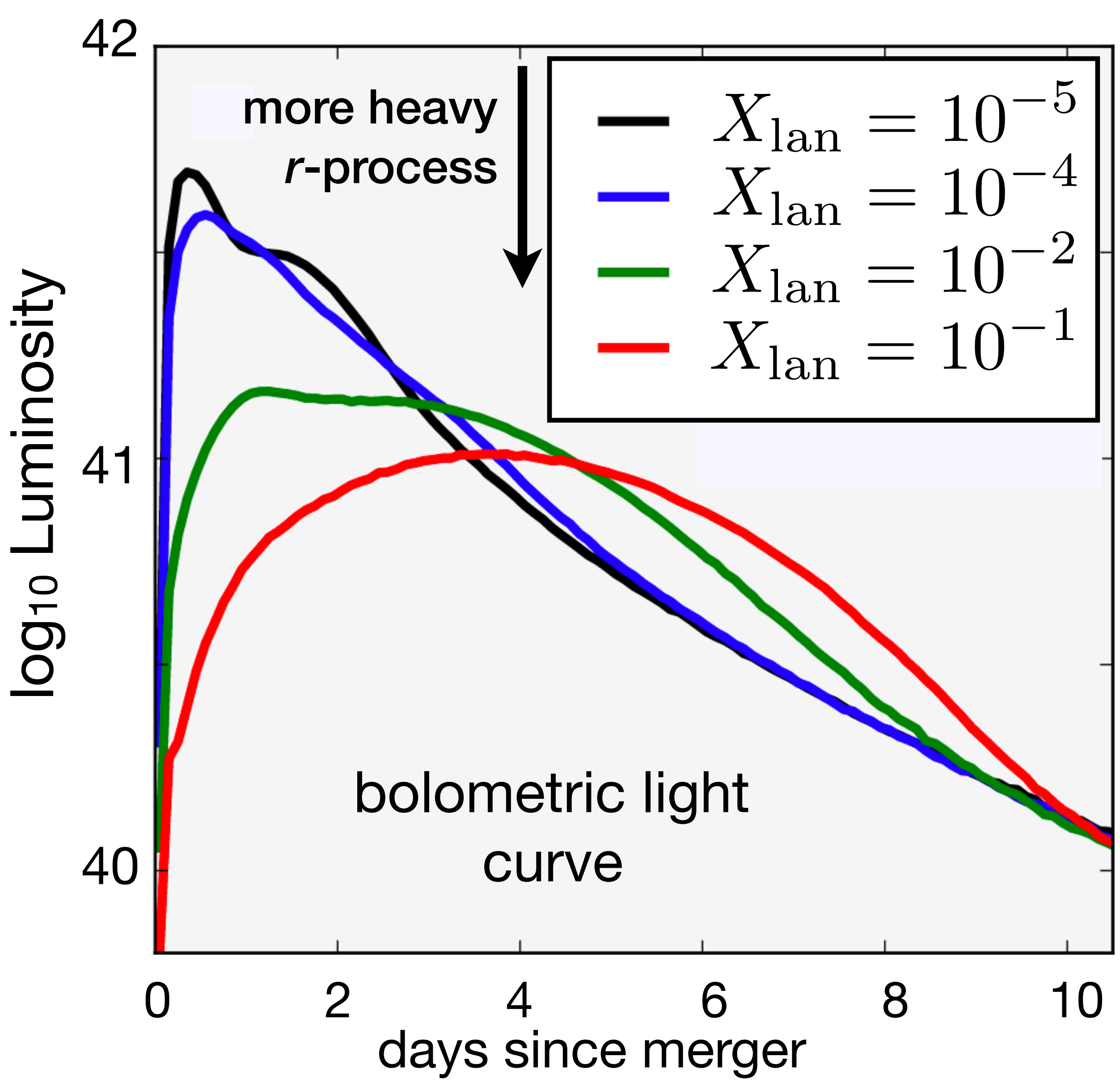
r-process evidence



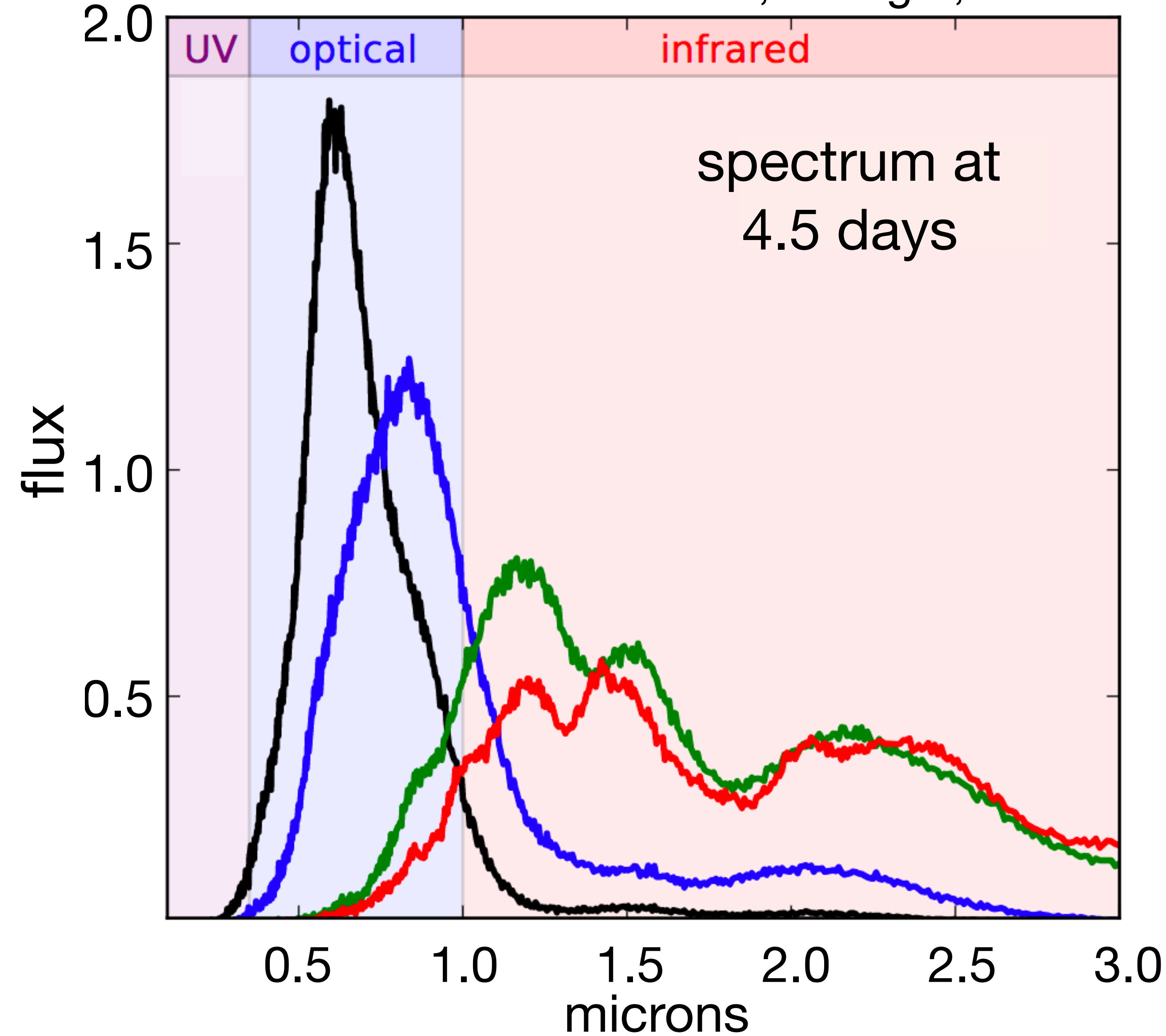
Longer, dimmer, redder light curves reveal the presence of heavy *r*-process material

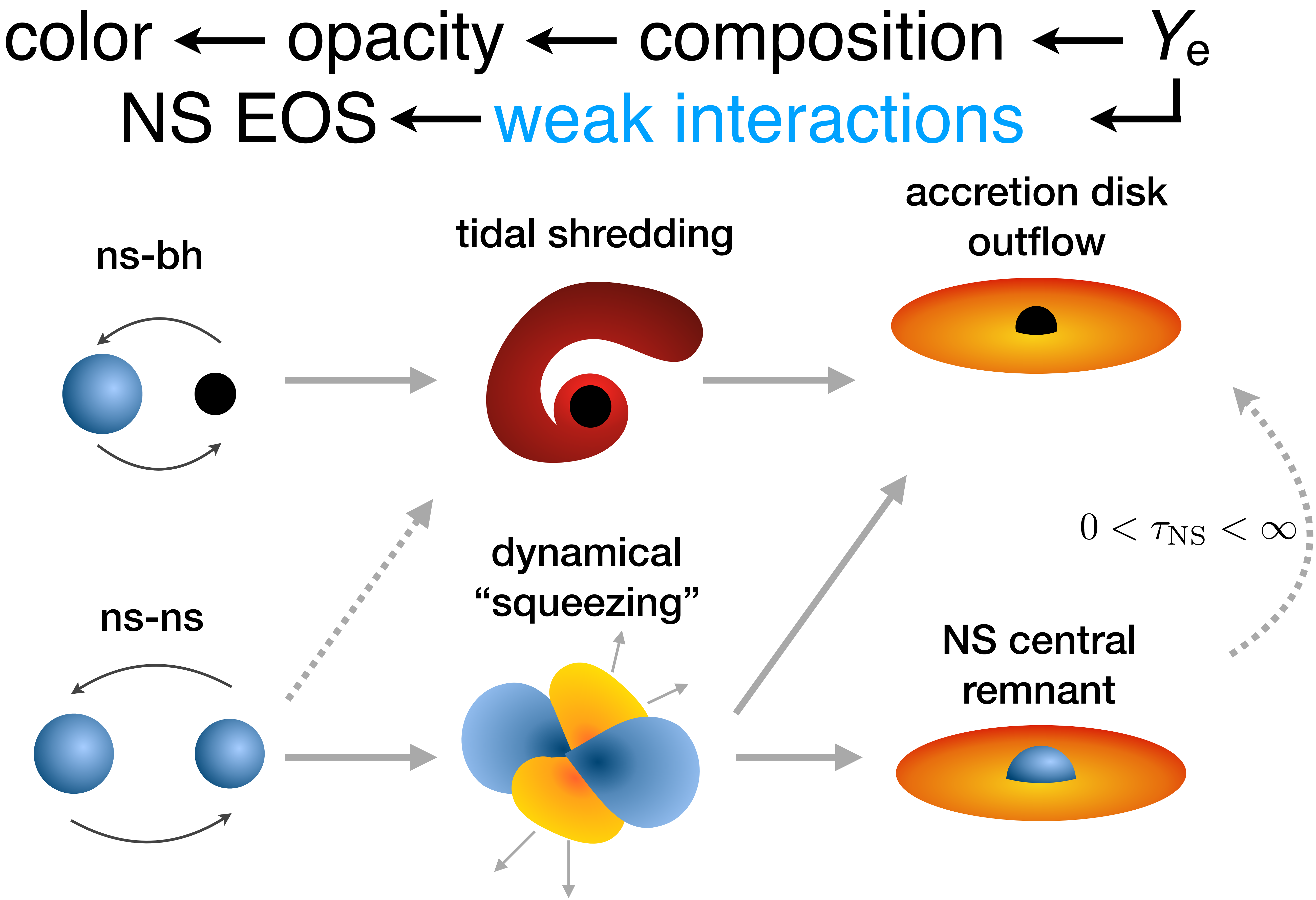
diffusion time: $t_{\rm diff} \approx \left(\frac{M\kappa}{vc}\right)^{1/2}$ **adiabatic losses:** $E_{\rm phot} \sim t^{-1}$

line blanketing at optical wavelengths

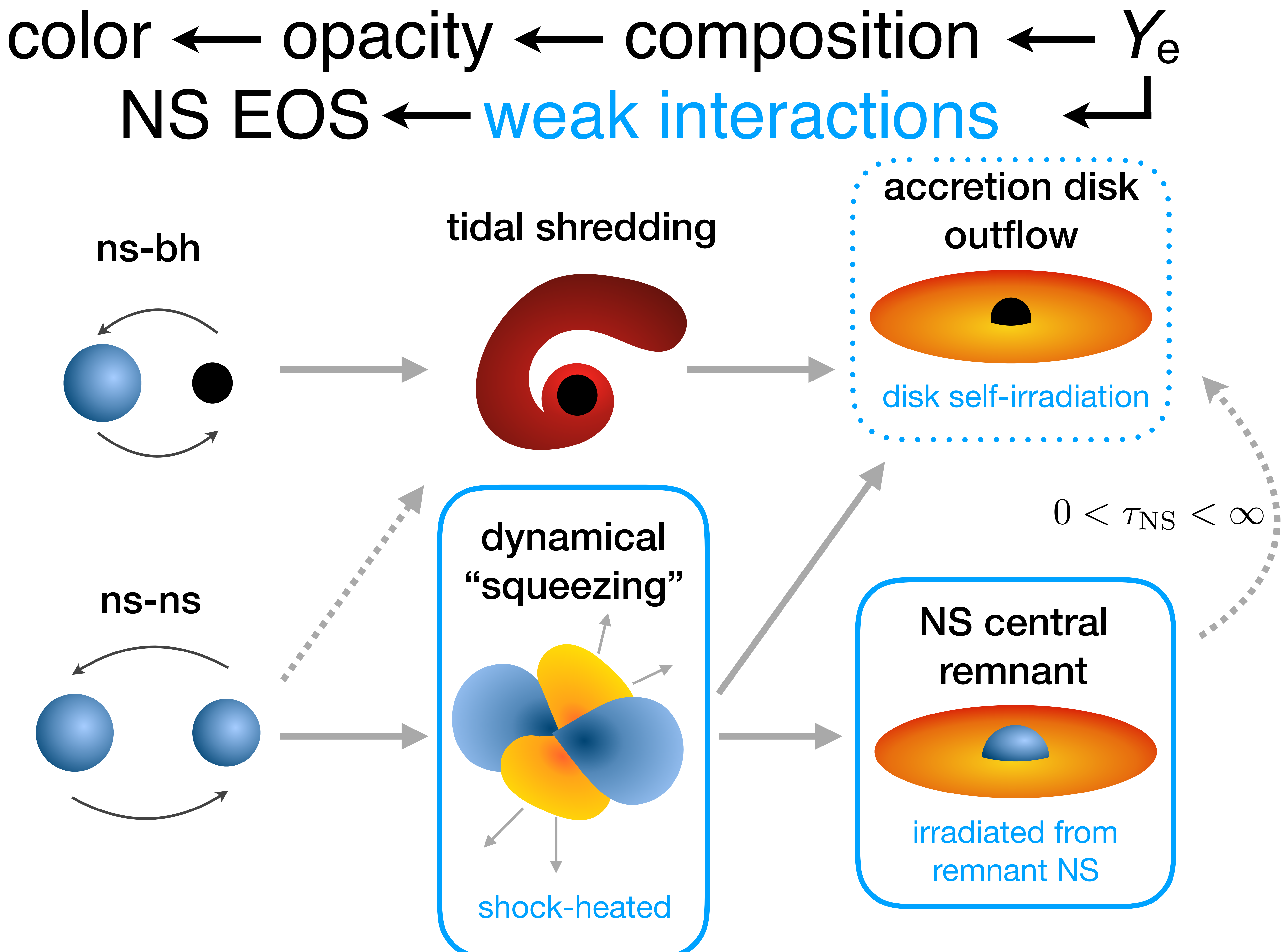


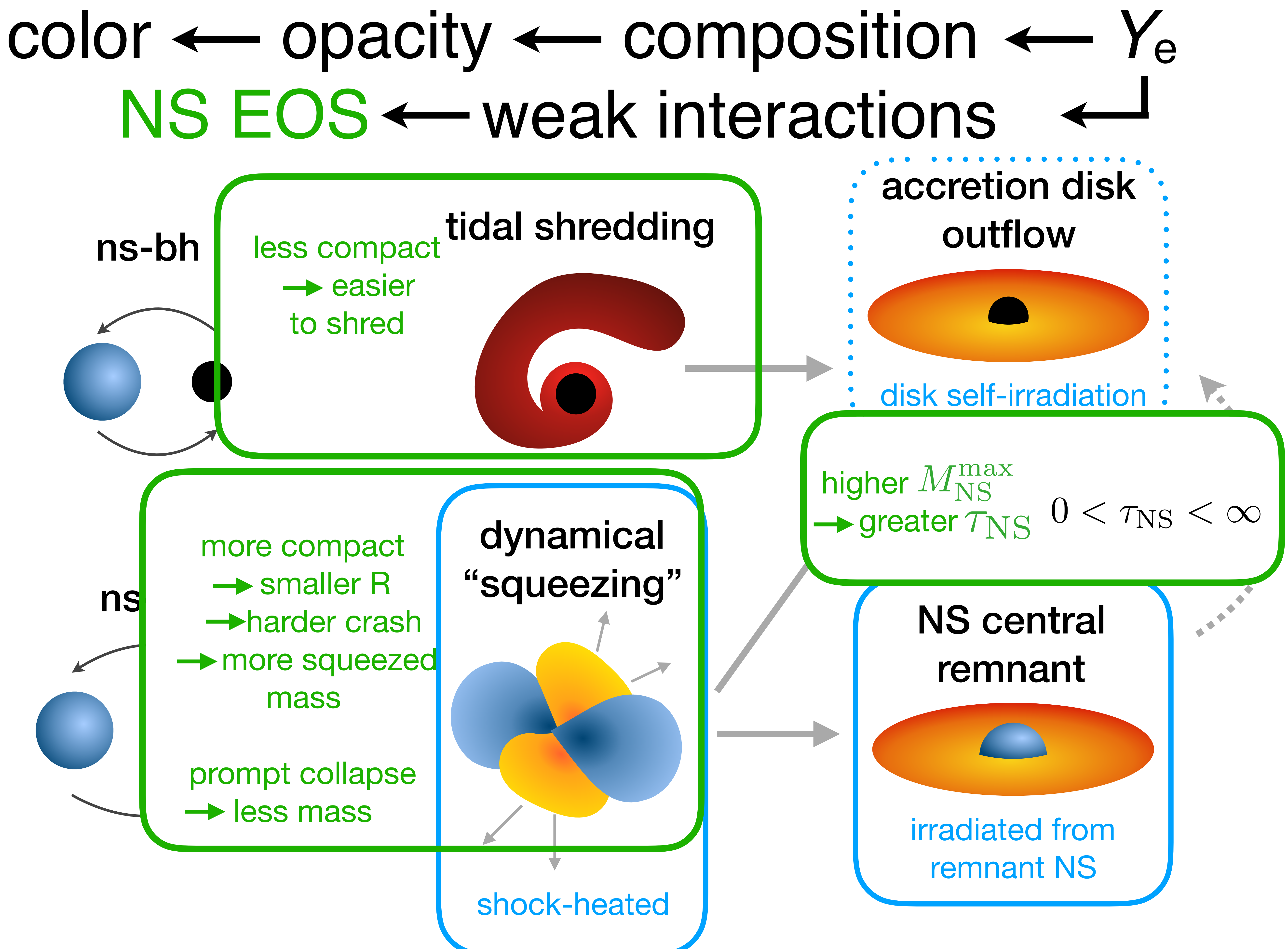
Kasen, Metzger, **JB**+17





color ← opacity ← composition ← Y_e
NS EOS ← weak interactions
ns-bh
tidal shredding
accretion disk outflow
ns-ns
dynamical “squeezing”
NS central remnant
$0 < \tau_{NS} < \infty$

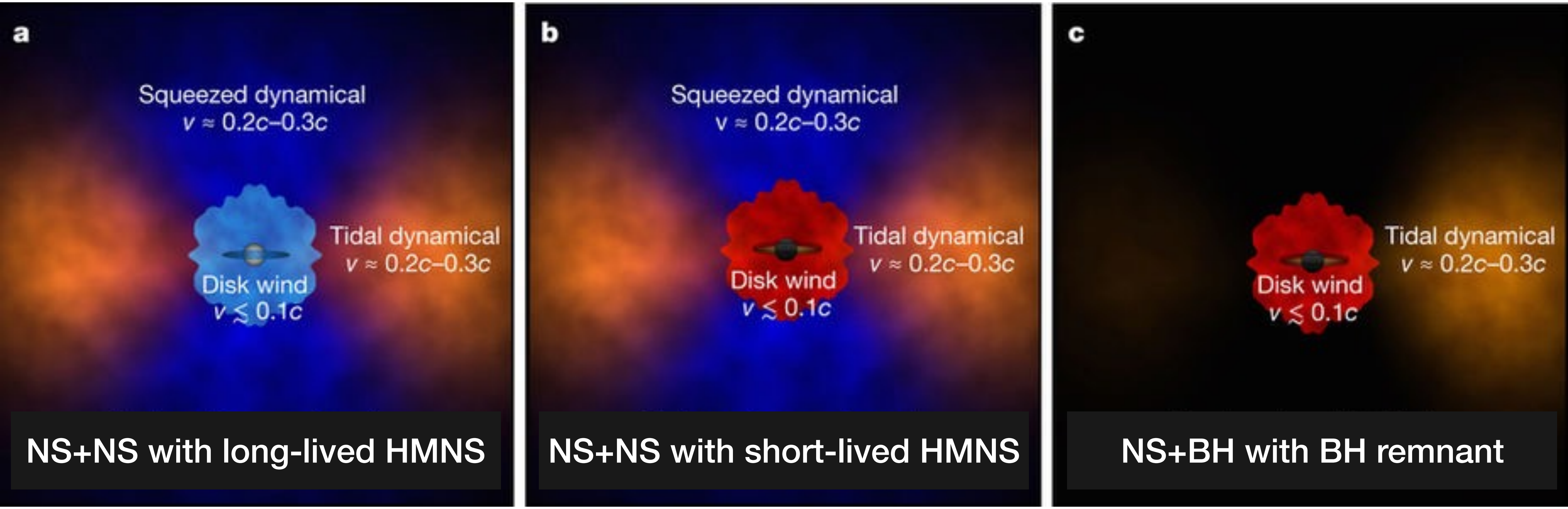

color ← opacity ← composition ← Y_e
NS EOS ← weak interactions
accretion disk outflow
disk self-irradiation
tidal shredding
ns-bh
ns-ns
dynamical "squeezing"
shock-heated
NS central remnant
irradiated from remnant NS
$0 < \tau_{\rm NS} < \infty$



color ⟵ opacity ⟵ composition ⟵ Y_e
NS EOS ⟵ weak interactions
ns-bh
less compact
→ easier
to shred
tidal shredding
accretion disk
outflow
disk self-irradiation
higher M_{NS}^{max}
→ greater τ_{NS}
$0 < \tau_{NS} < \infty$
ns
more compact
→ smaller R
→ harder crash
→ more squeezed
mass
prompt collapse
→ less mass
dynamical
“squeezing”
shock-heated
NS central
remnant
irradiated from
remnant NS

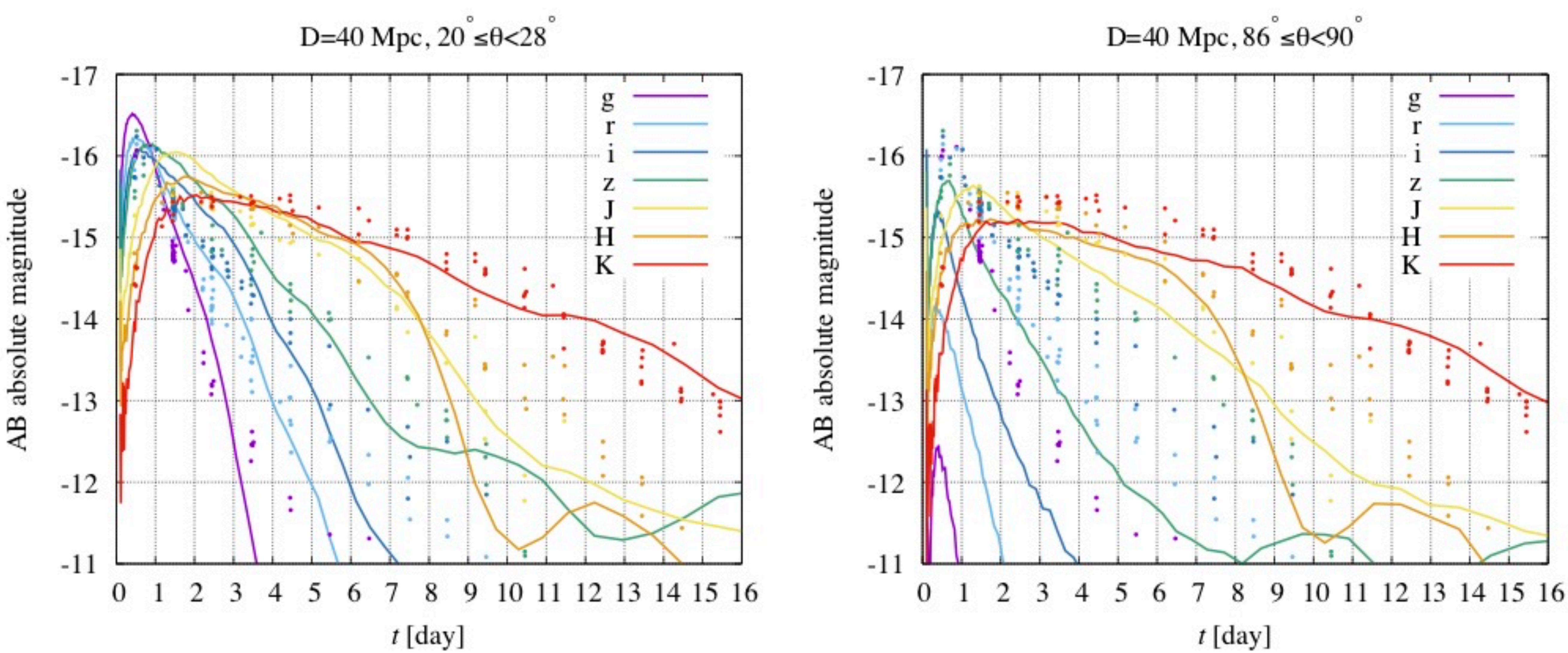
Sources of uncertainty

1. Asymmetry and multiple components



How does the emission vary with viewing angle?
How well do (superposed) 1D models represent more complicated geometries?
How much to we trust the interpretation of each component

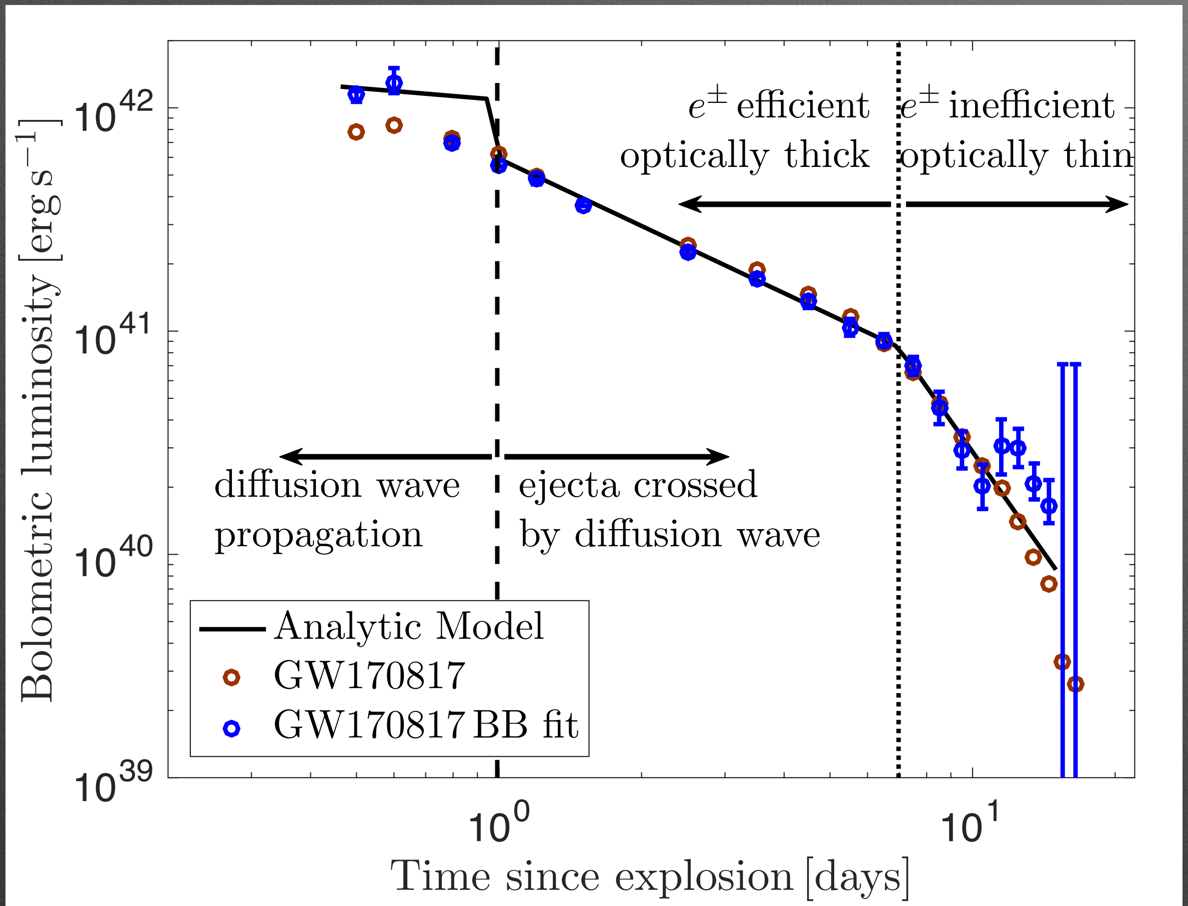
2D kilonova simulations



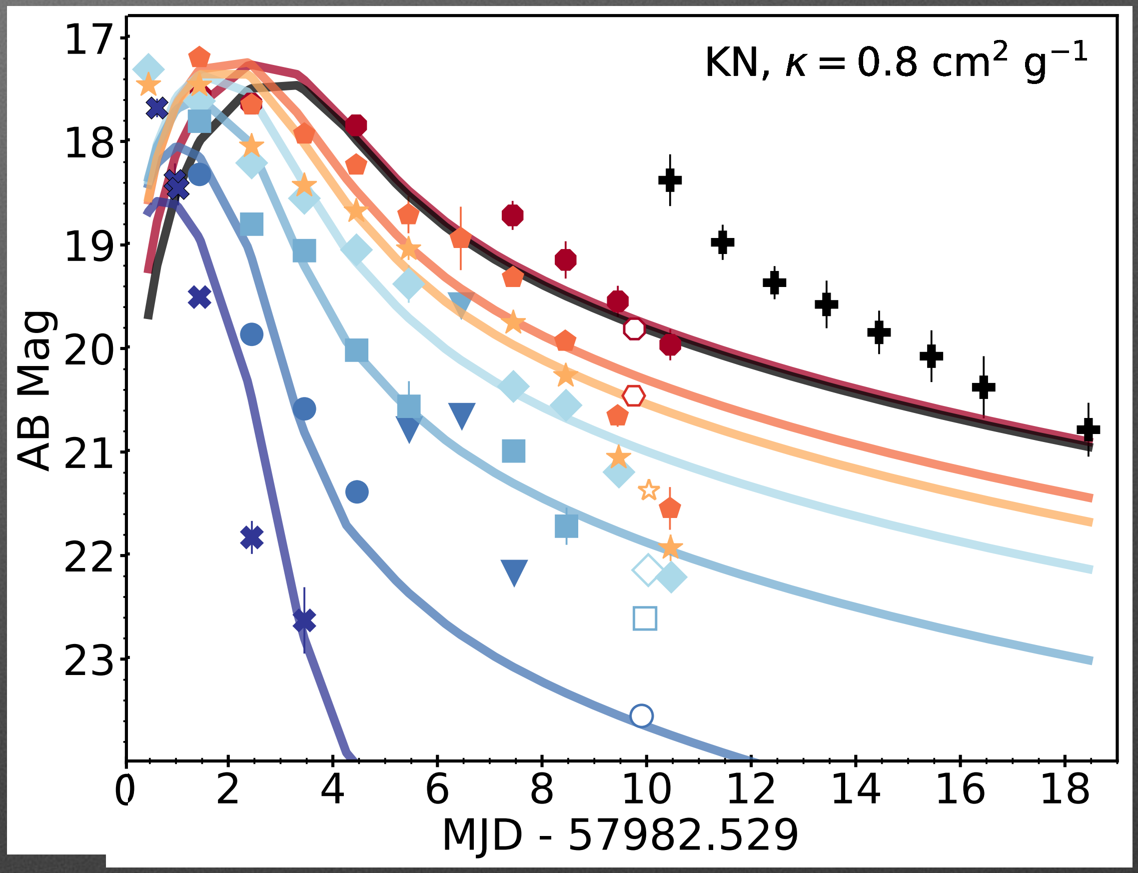
Kawaguchi et al. 2018
See also Wollaeger et al. 2018

- Viewing angle makes a difference
- Reprocessing of one component by another may be very important

Or maybe not?



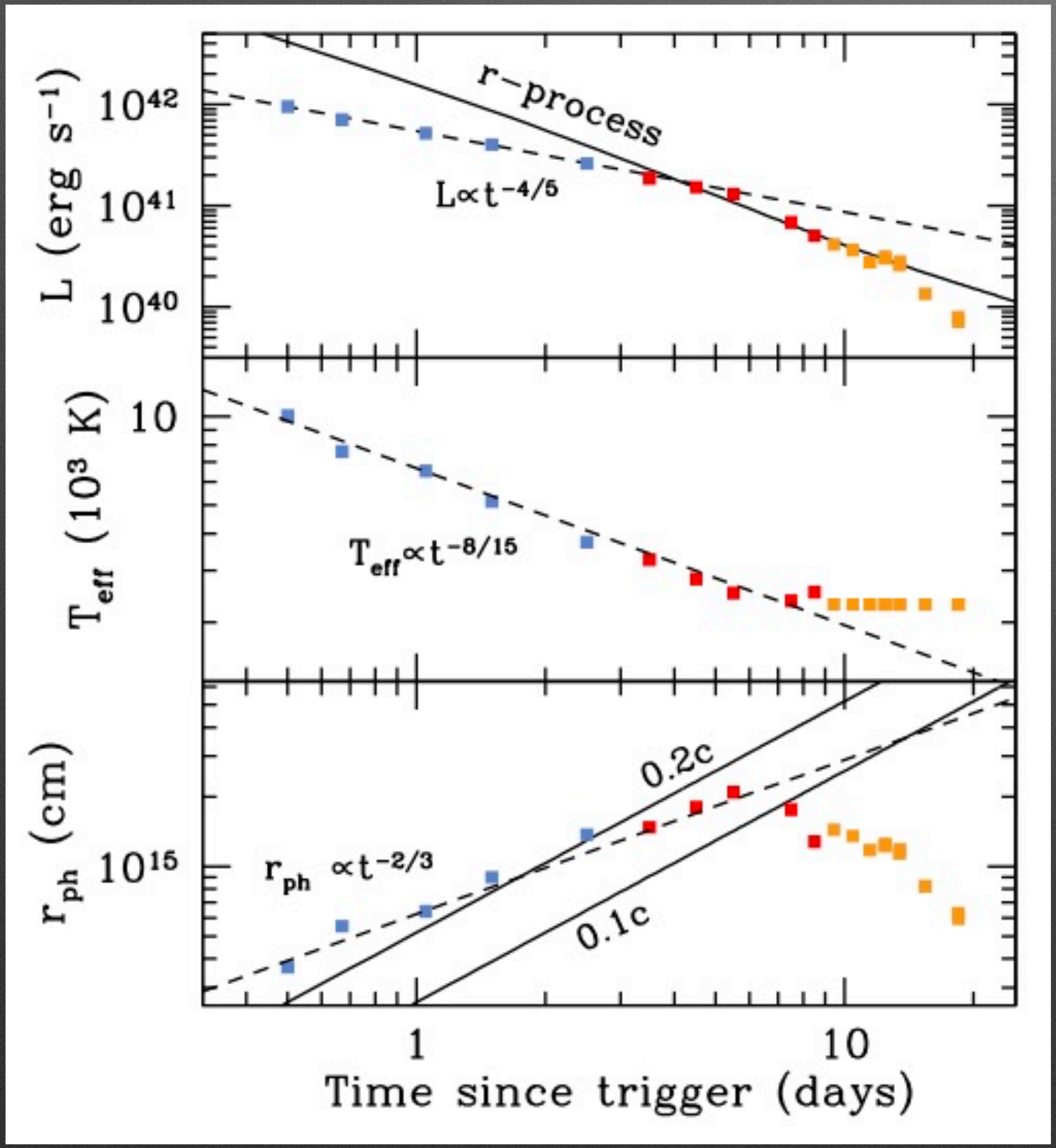
Waxman et al. 2017



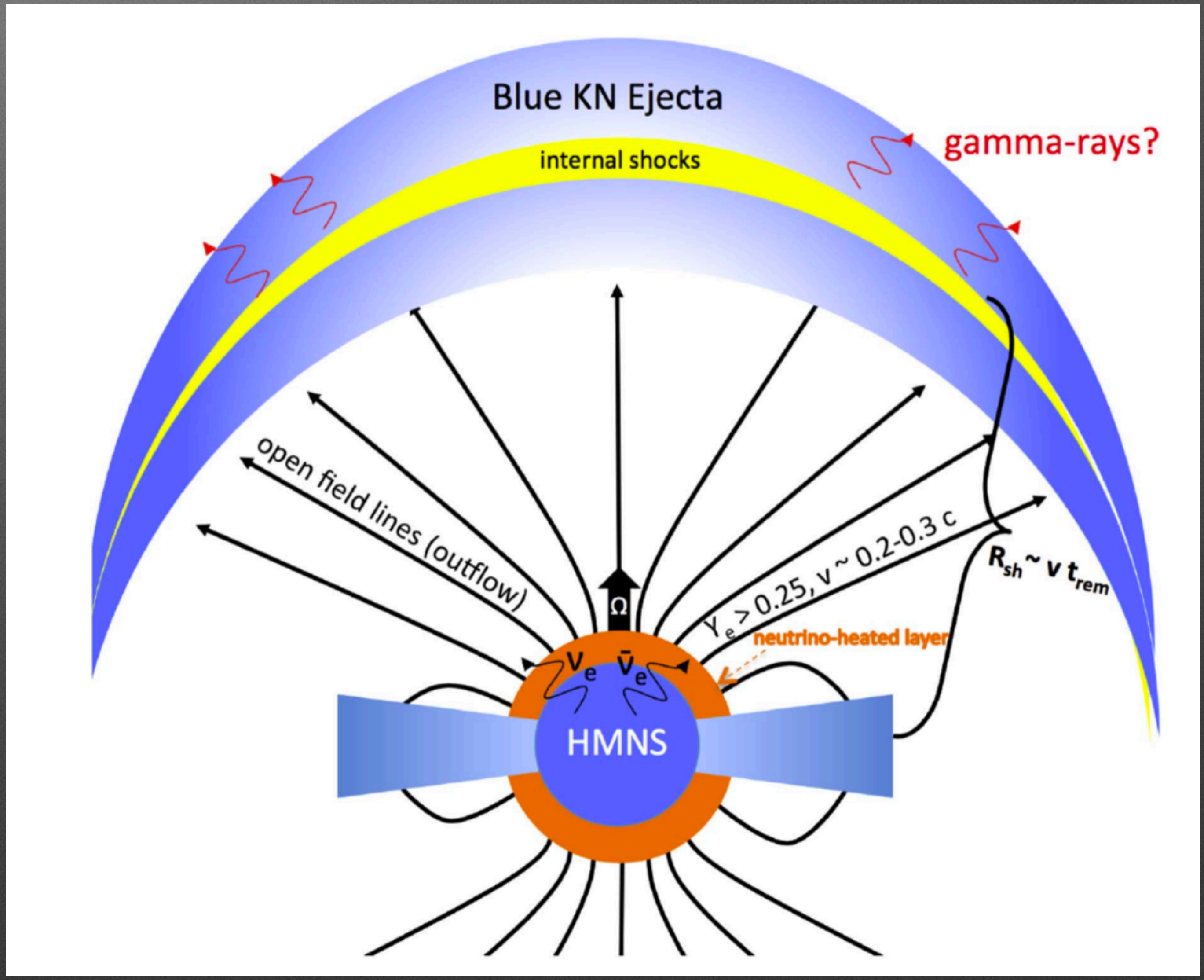
Cowperthwaite et al. 2017

- Waxman et al. (2017) argue that a single component with a low lanthanide abundance (X_{lan} ~ 10^{-3}) can explain the whole light curve, which would be insufficient to explain solar lanthanide abundances

How well do we really know the blue component?



Piro & Kollmeier 2018

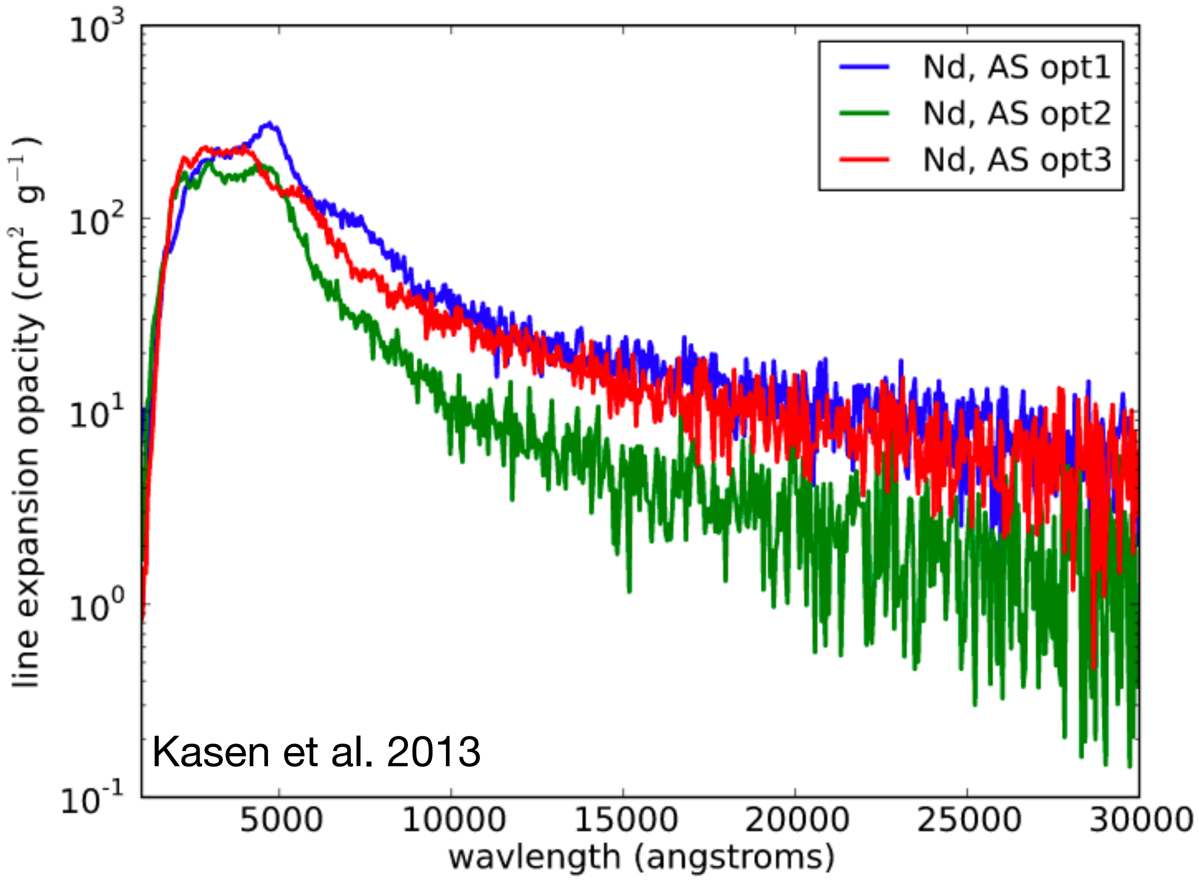


Metzger et al. 2018

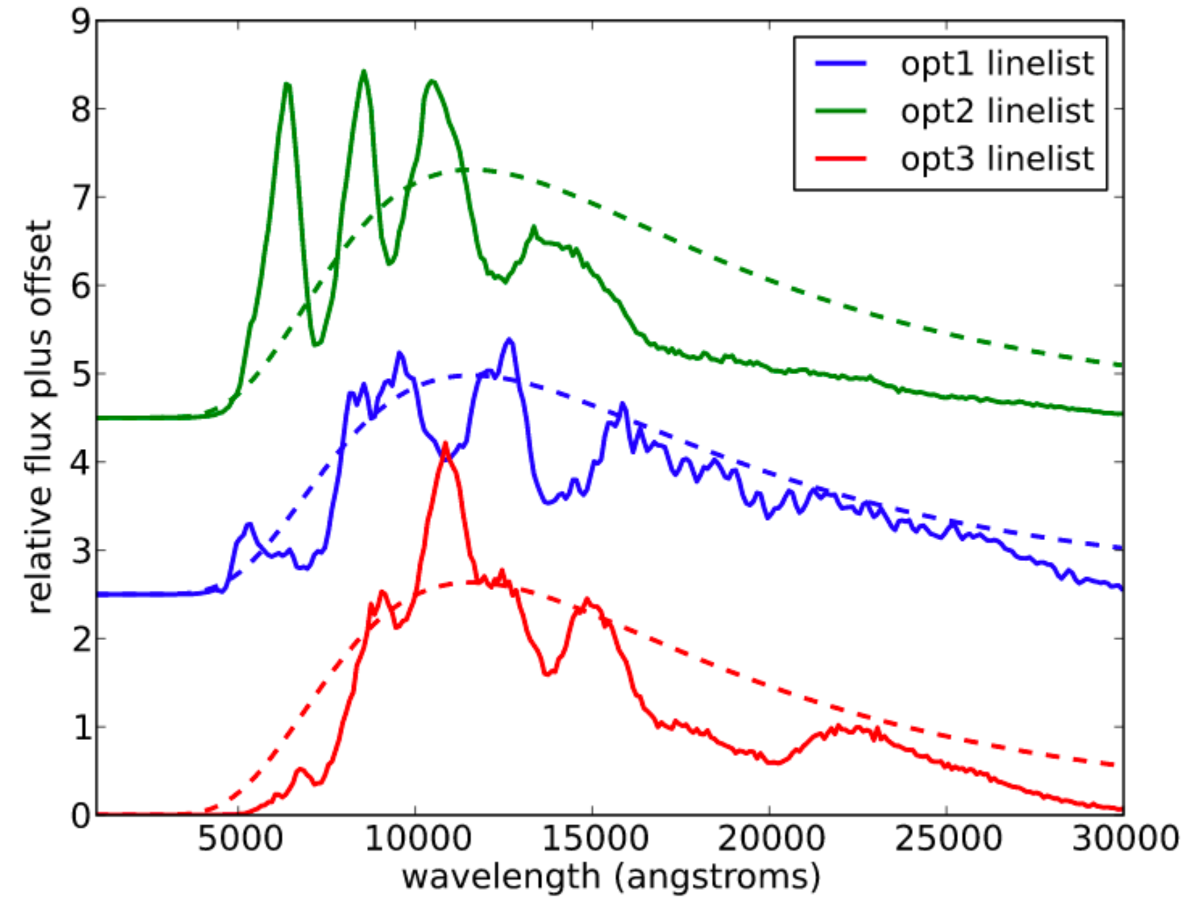
Sources of uncertainty

2. Atomic data and opacities

Opacities



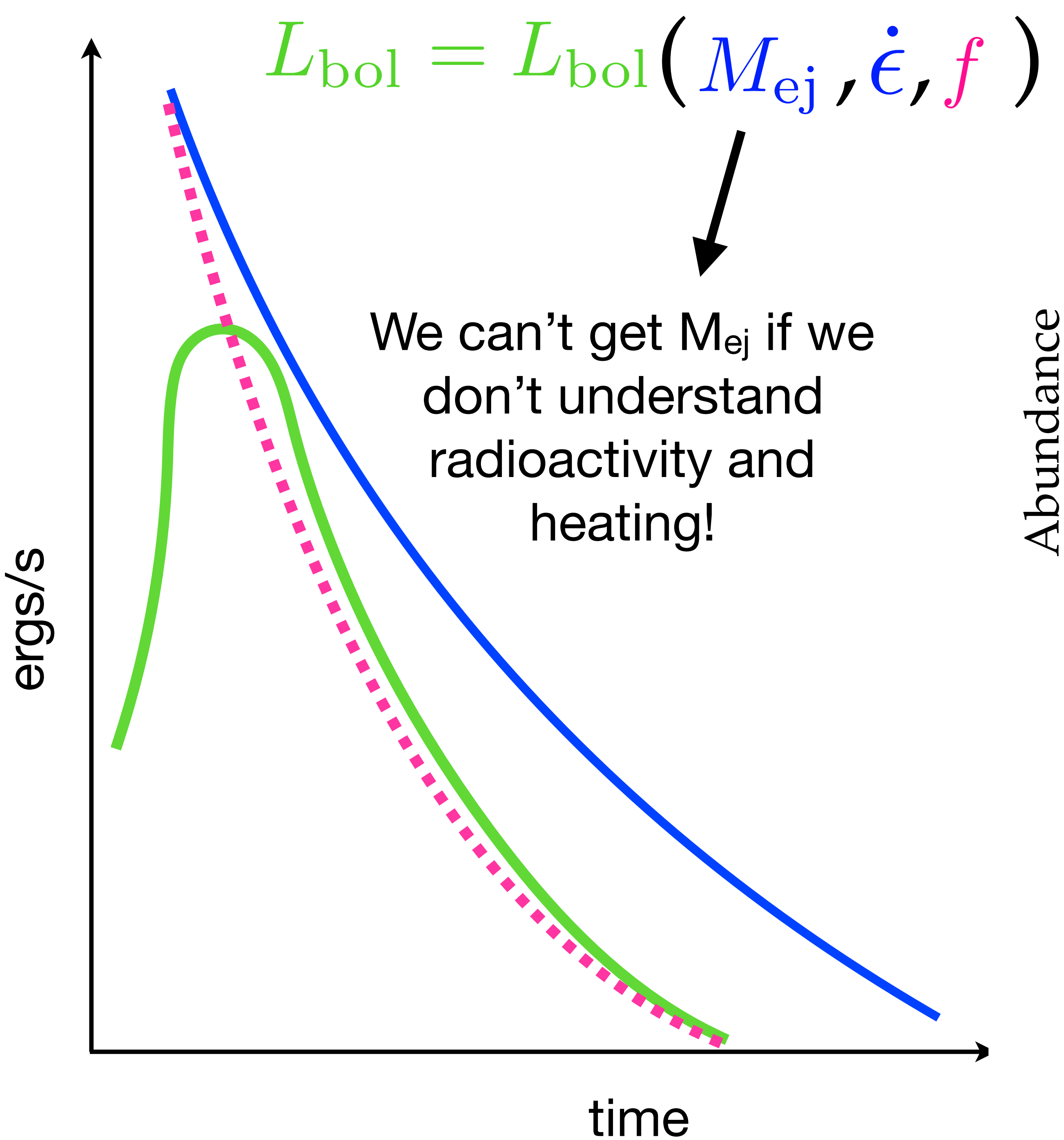
Observables (spectrum at 2.5 days)



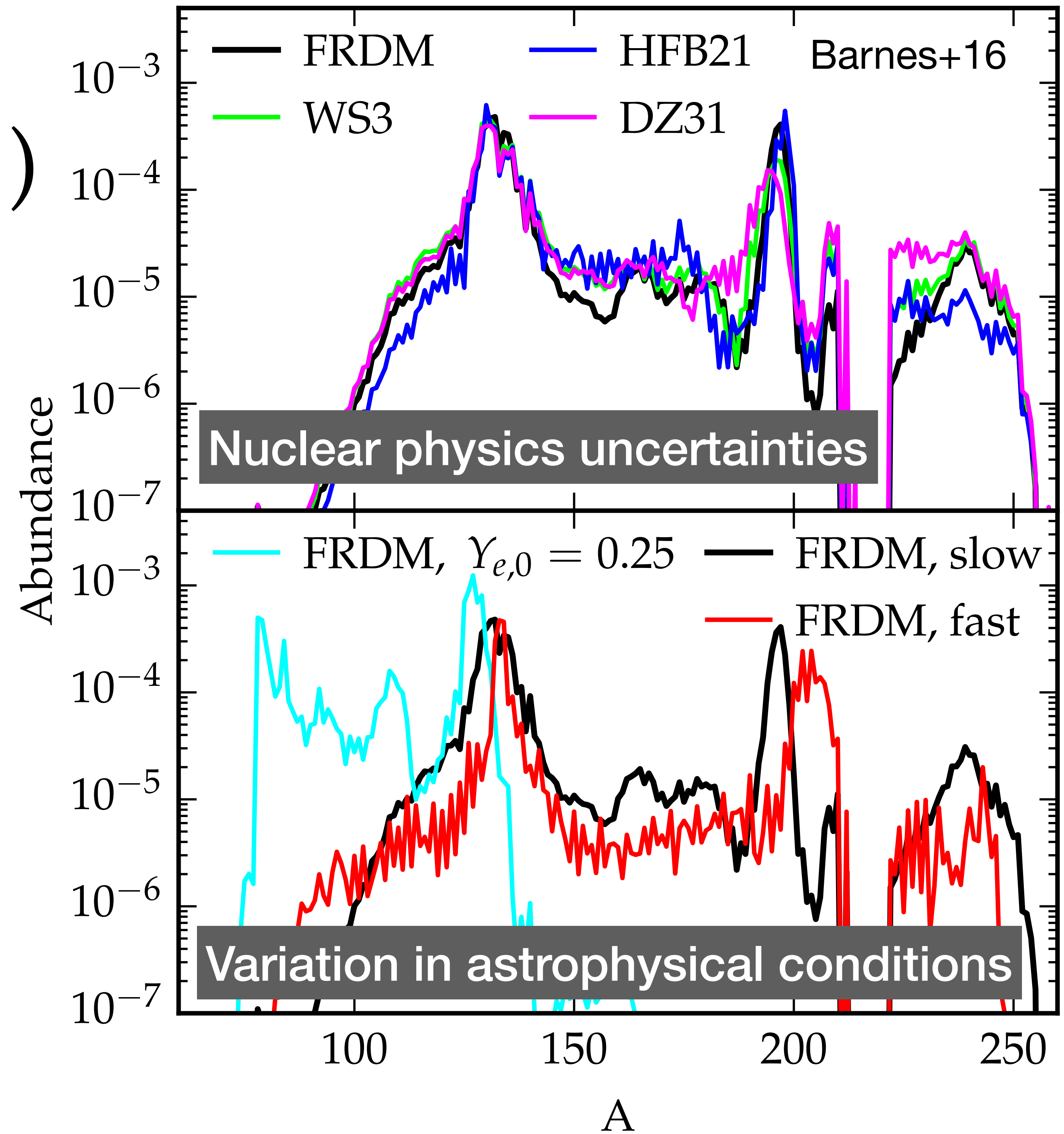
What will allow us to be confident in spectra line identifications?

Sources of uncertainty

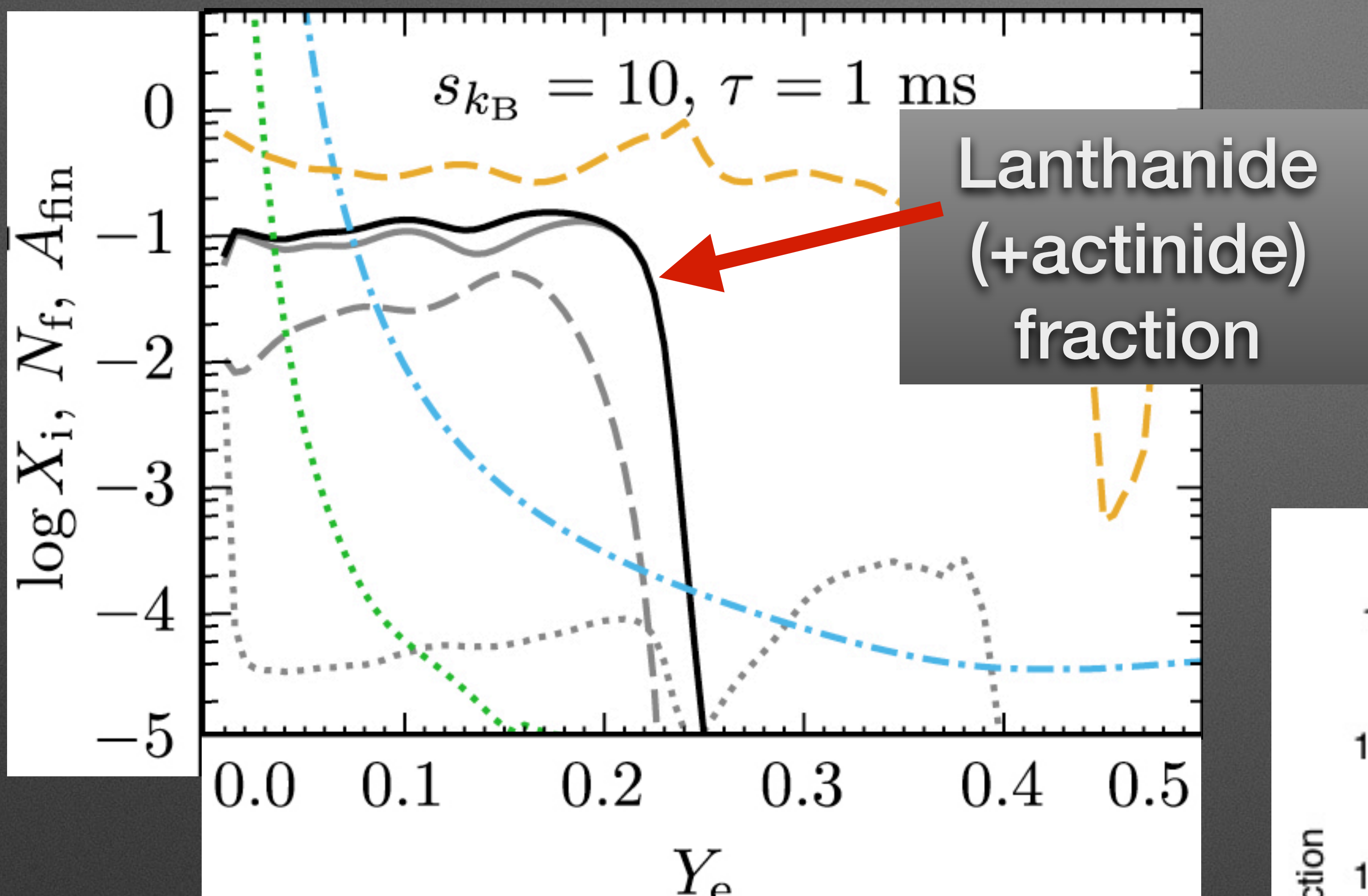
3. Nuclear heating



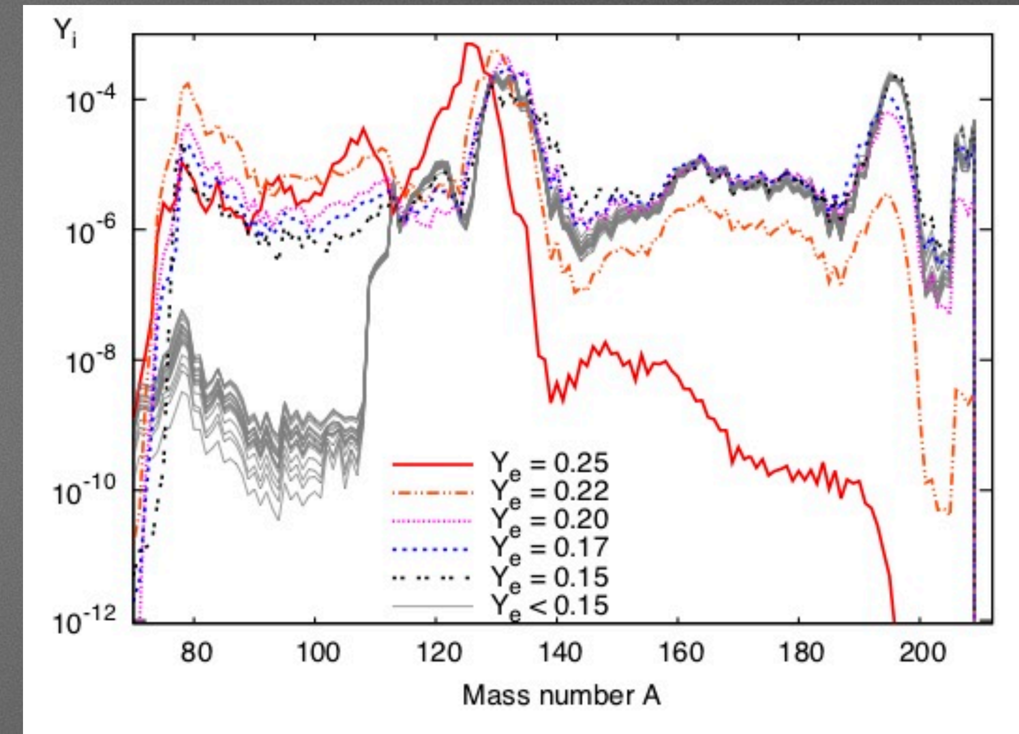
(abundances are a proxy for different histories of radiation)



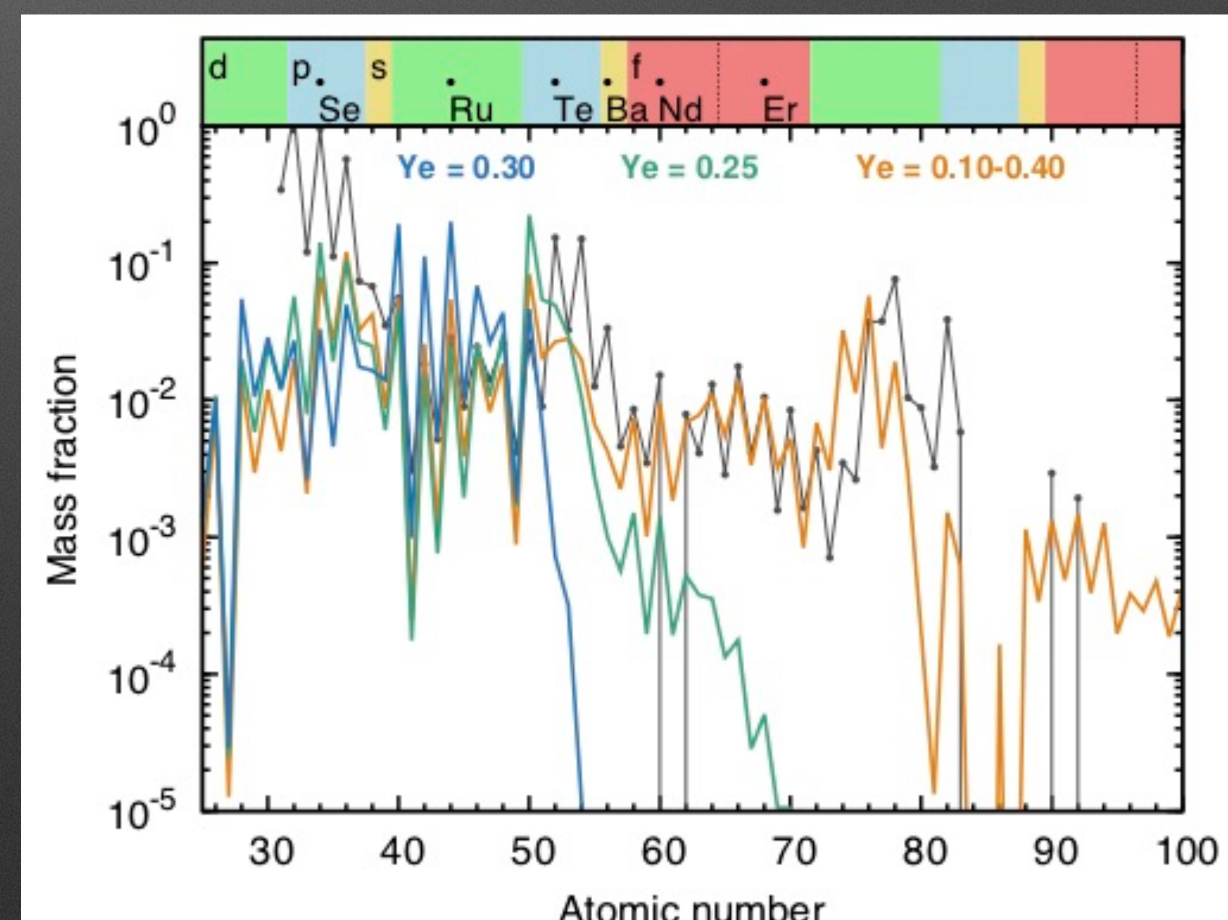
Nucleosynthesis



Lippuner & Roberts 2015



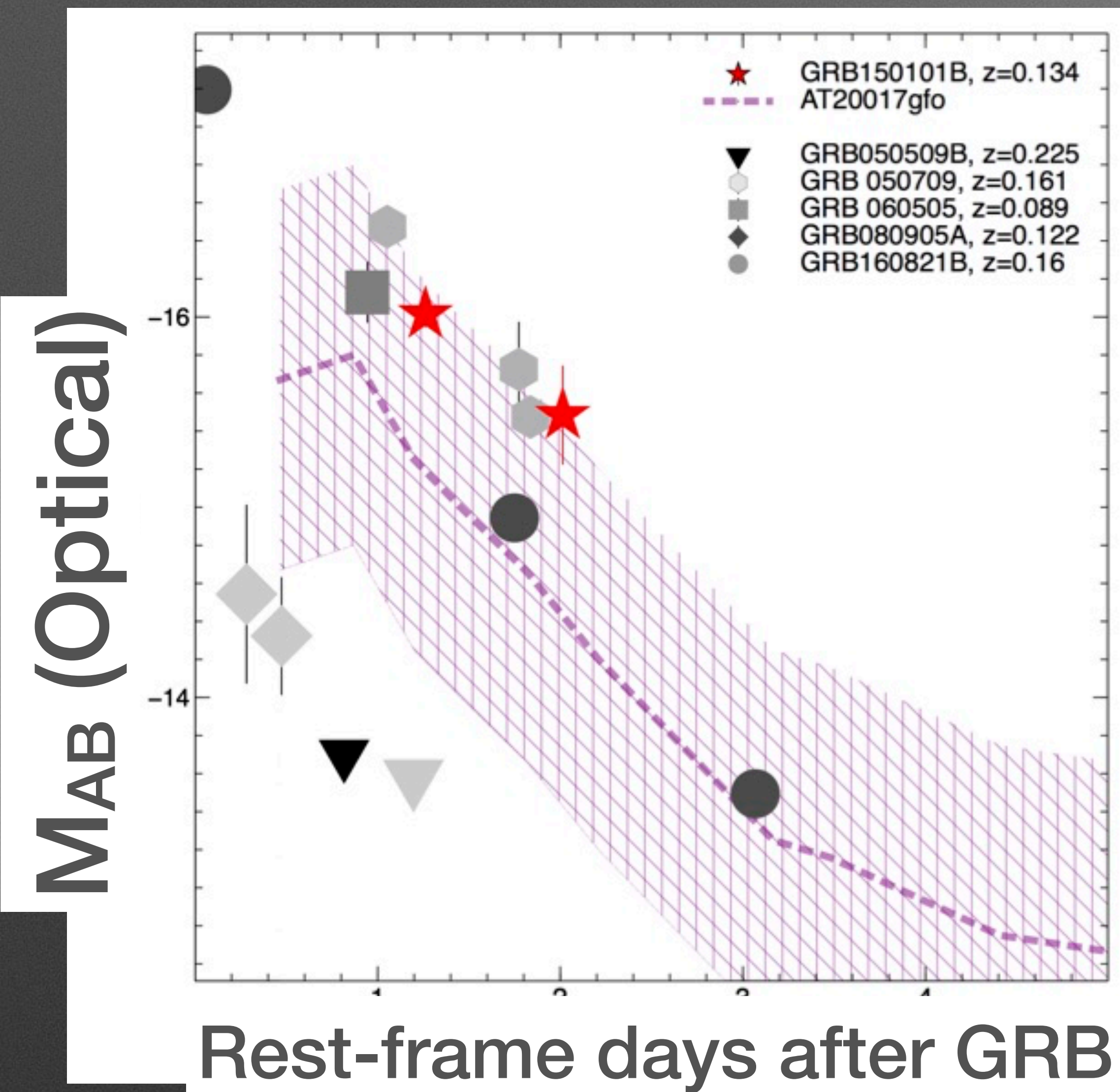
Korobkin et al. 2012



Tanaka et al. 2018

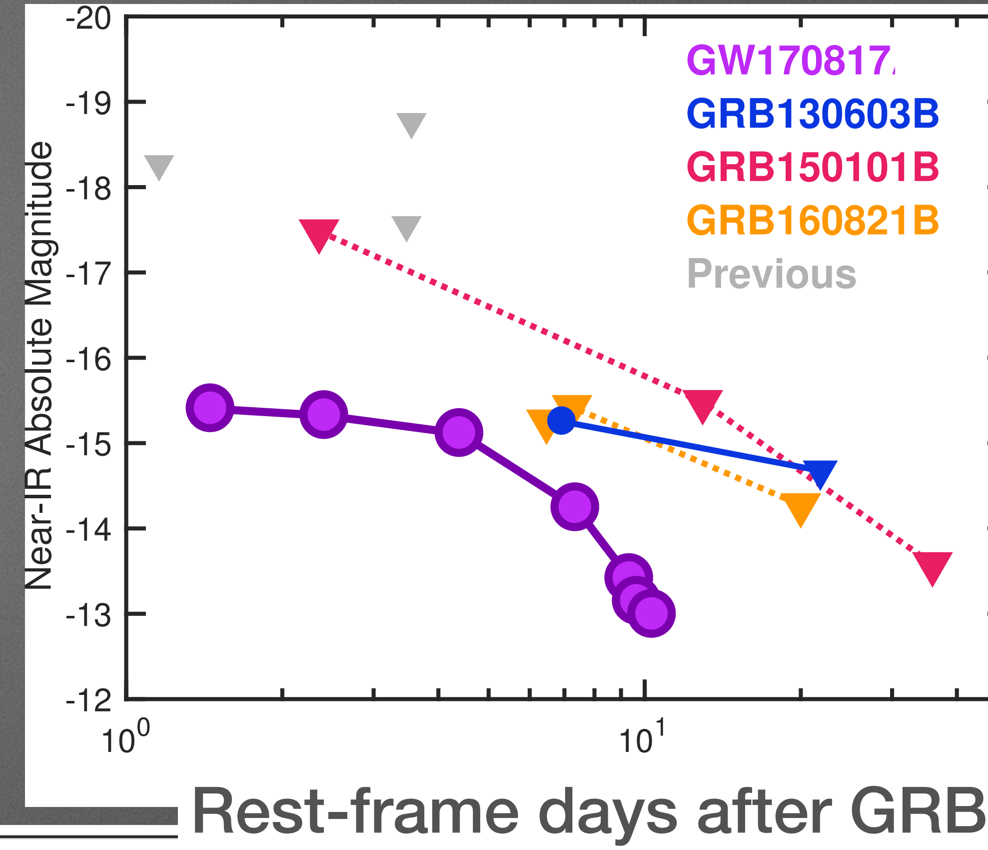
- There is a production threshold below Y_e~0.23 in merger calculations: lanthanide fraction is not really a free knob

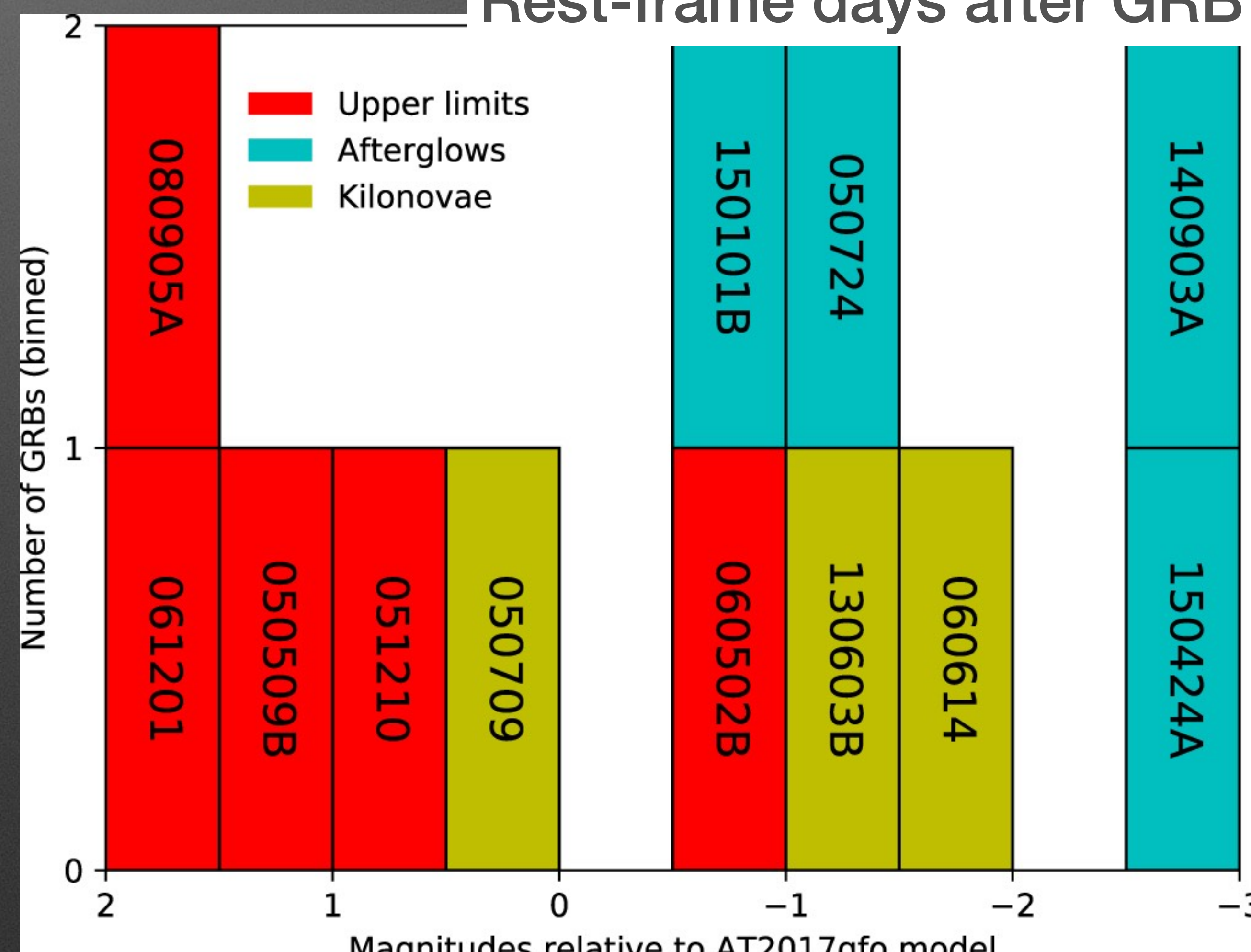
Short GRBs



Troja et al. 2018

Fong et al. 2017





Gompertz et al. 2018

- Despite confusion with afterglows, it is clear that there are short GRBs with counterparts *fainter* than 170817 at similar epochs