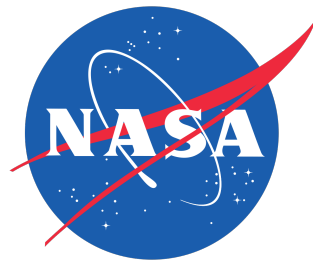


# Constraining the EOS through EM counterparts to BNS mergers

Ben Margalit,  
Einstein Fellow at UC Berkeley



**Berkeley**  
UNIVERSITY OF CALIFORNIA



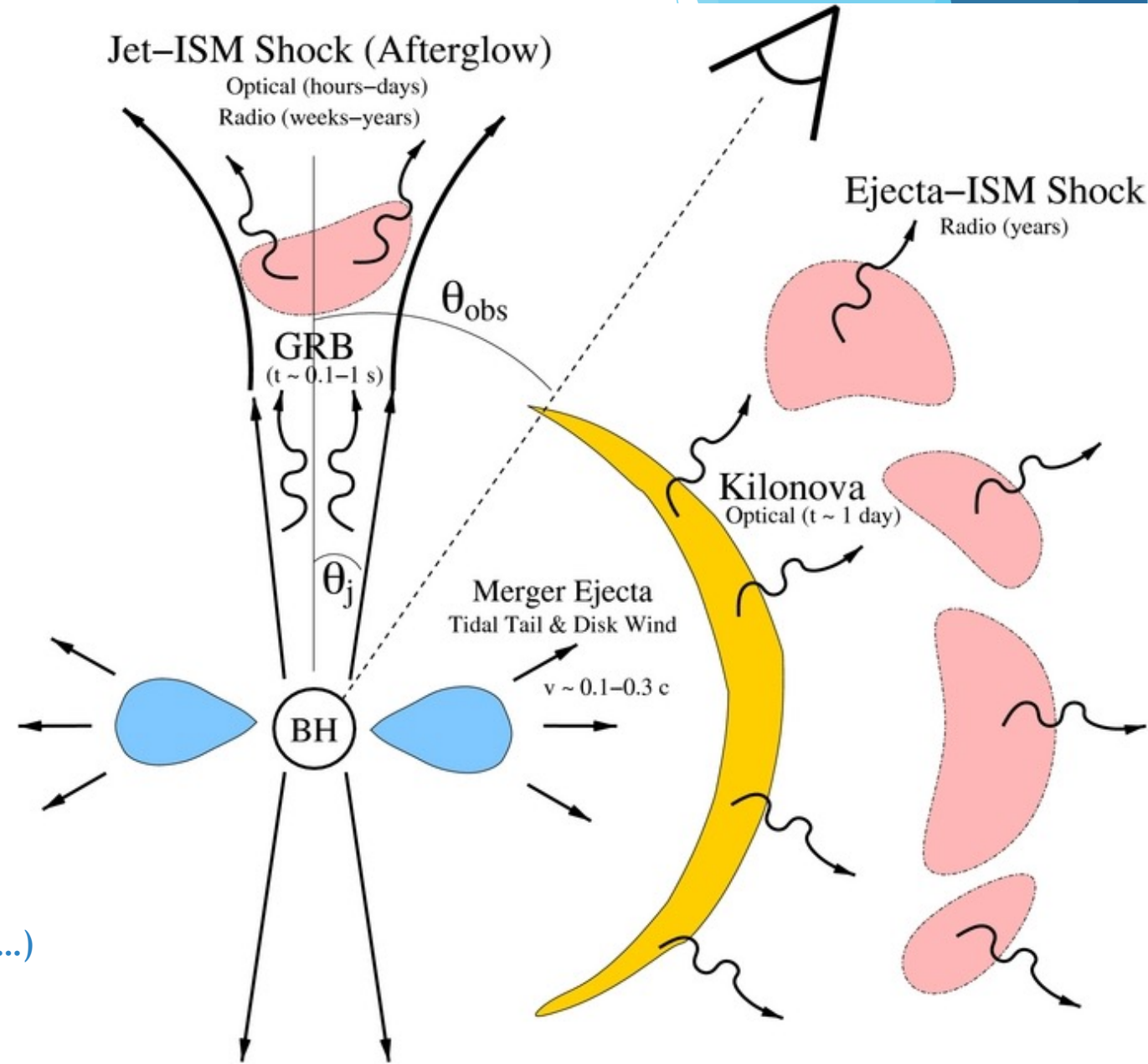
NASA Hubble  
Fellowship Program

ECT\* Workshop,  
June 14th 2021

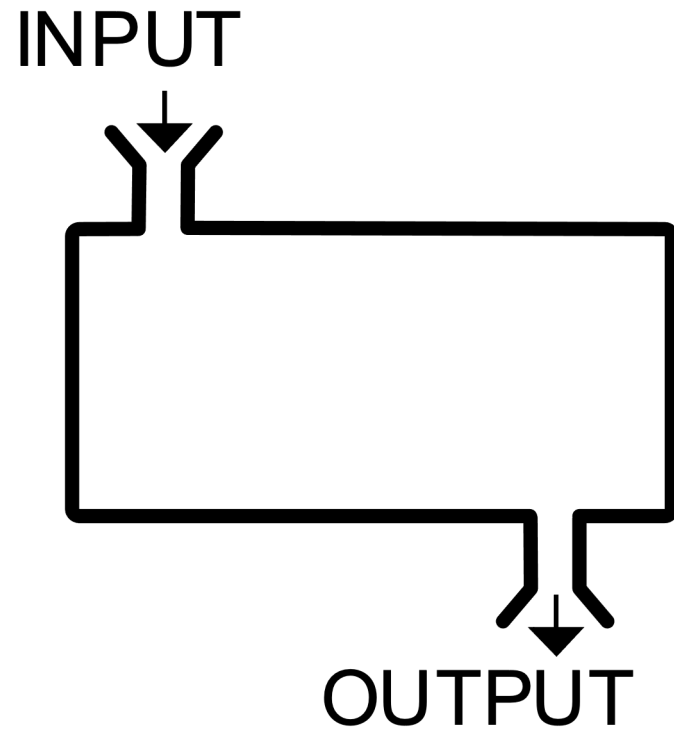
Metzger & Berger (2012)

## EM Counterparts:

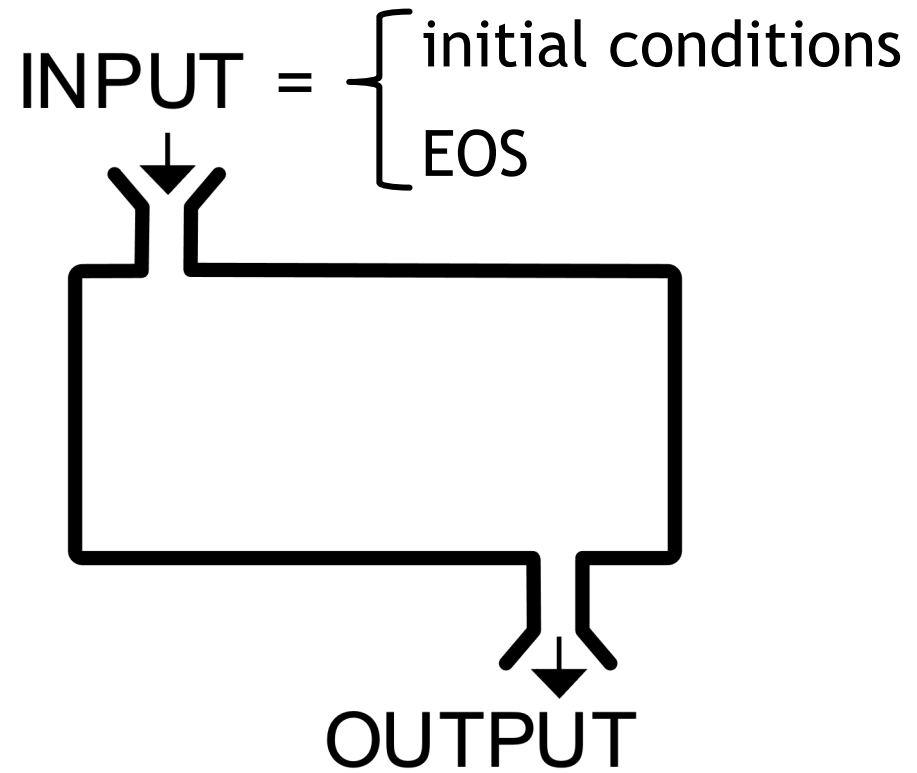
- short gamma-ray burst  
(Eichler+89; ...)
- kilonova  
(Li&Paczynski98; Metzger+10; Barnes&Kasen13; ...)
- UV flash  
(Metzger+15; Nakar&Piran17)
- radio flare  
(Nakar&Piran11; BM&Piran15,20; ...)
- fast radio burst?  
(Totani+13; Falcke&Rezzolla14; BM+19; Sridhar+20; ...)



## Relation to EOS:

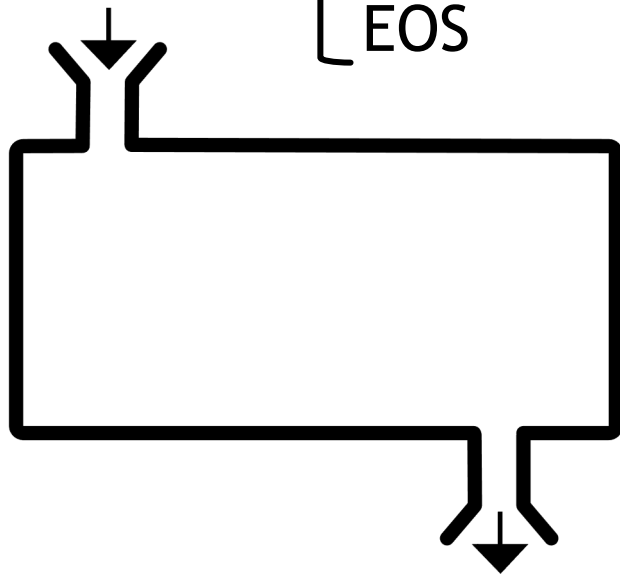


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INPUT = { initial conditions  
EOS

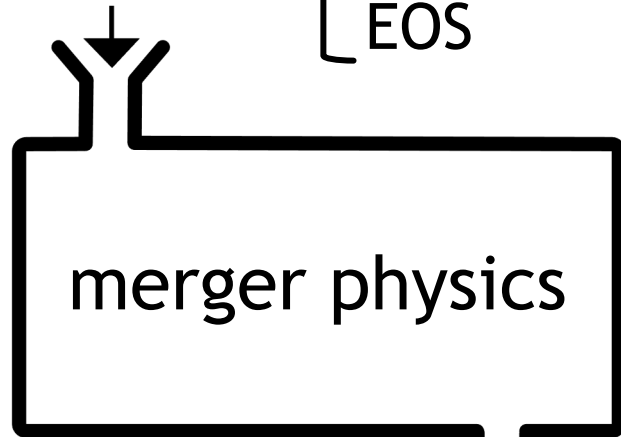


binary parameters:  
mass, mass ratio,  
spins, eccentricity  
orientation:  
distance, inclination

OUTPUT

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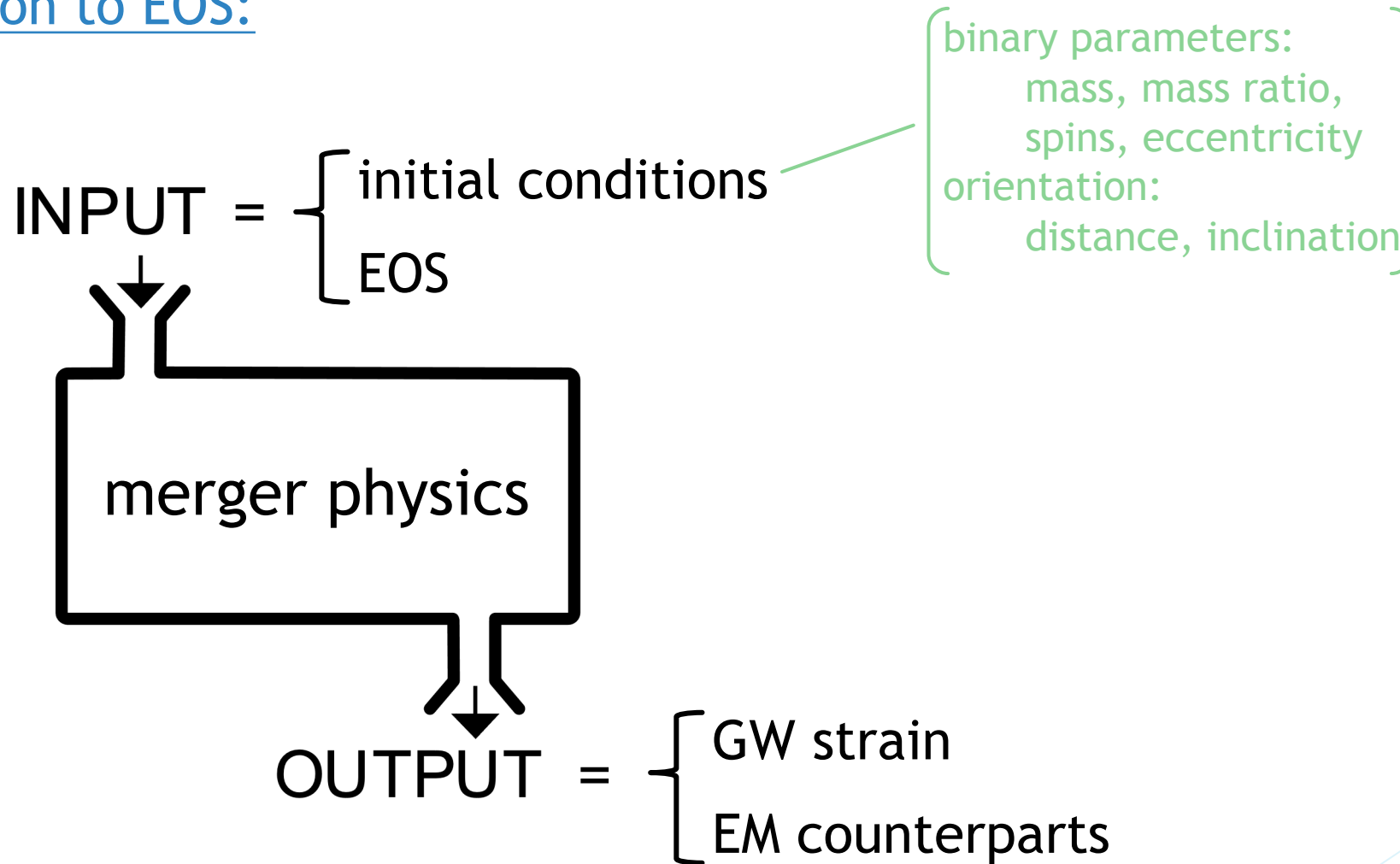
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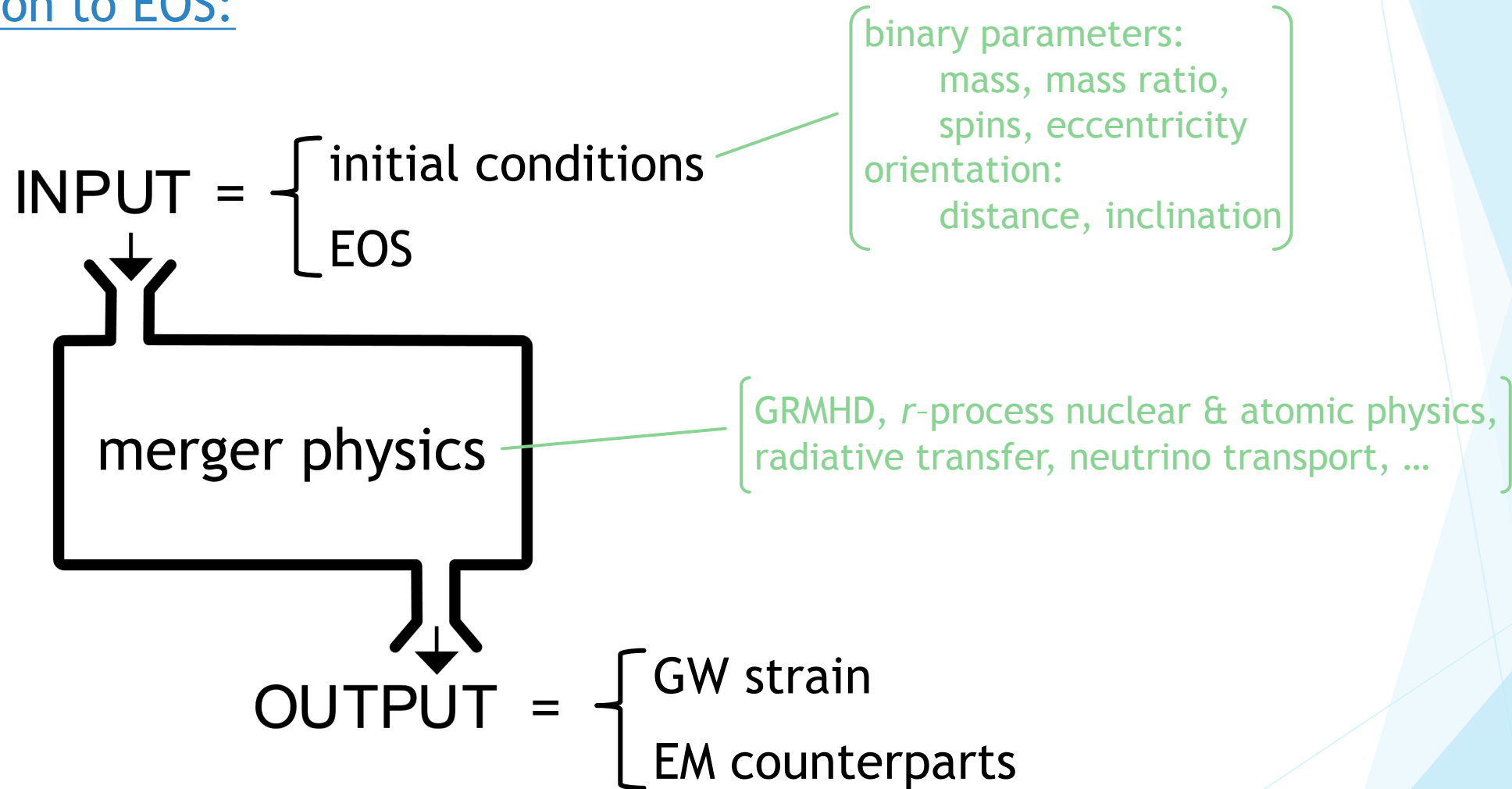
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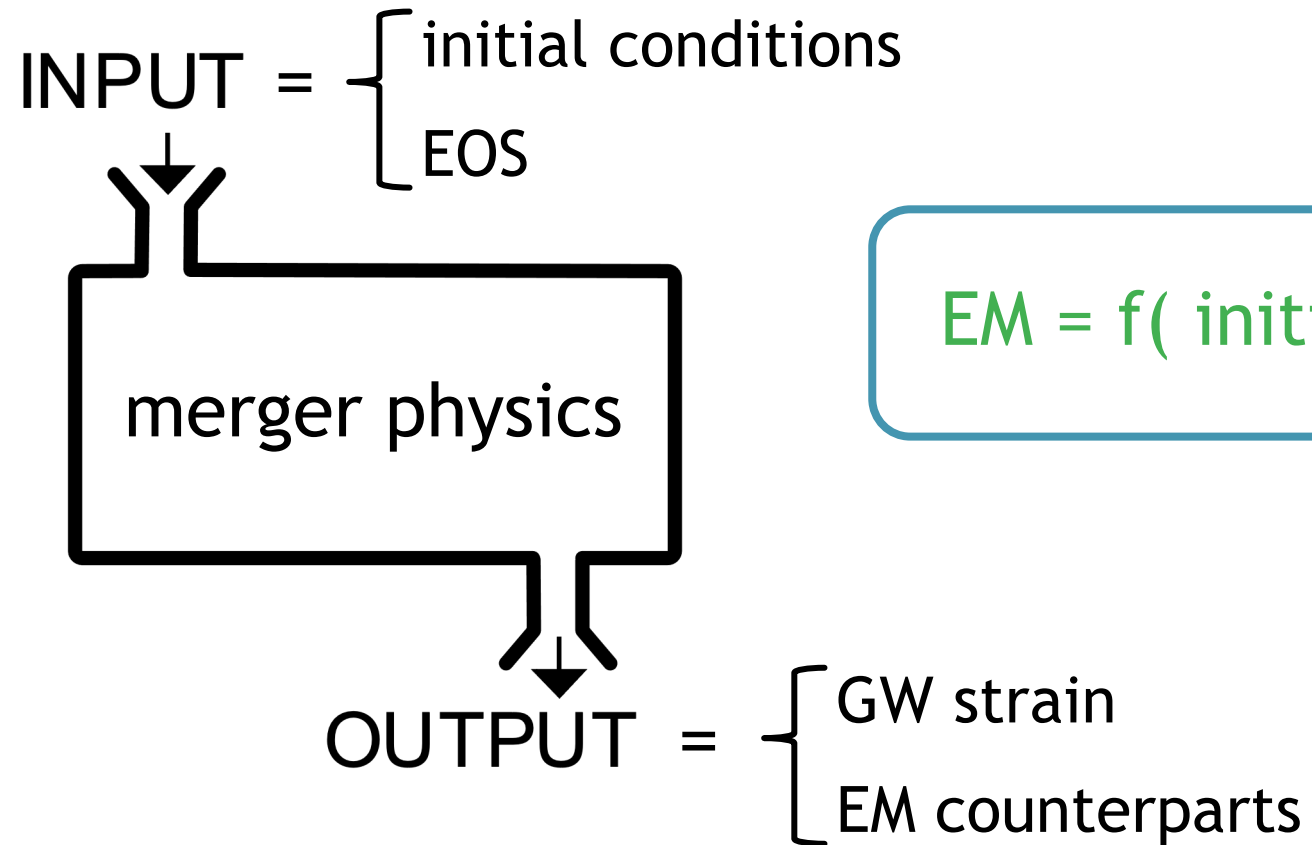


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$$EM = f(\text{initial conditions} \mid \text{EOS})$$

GRBs:

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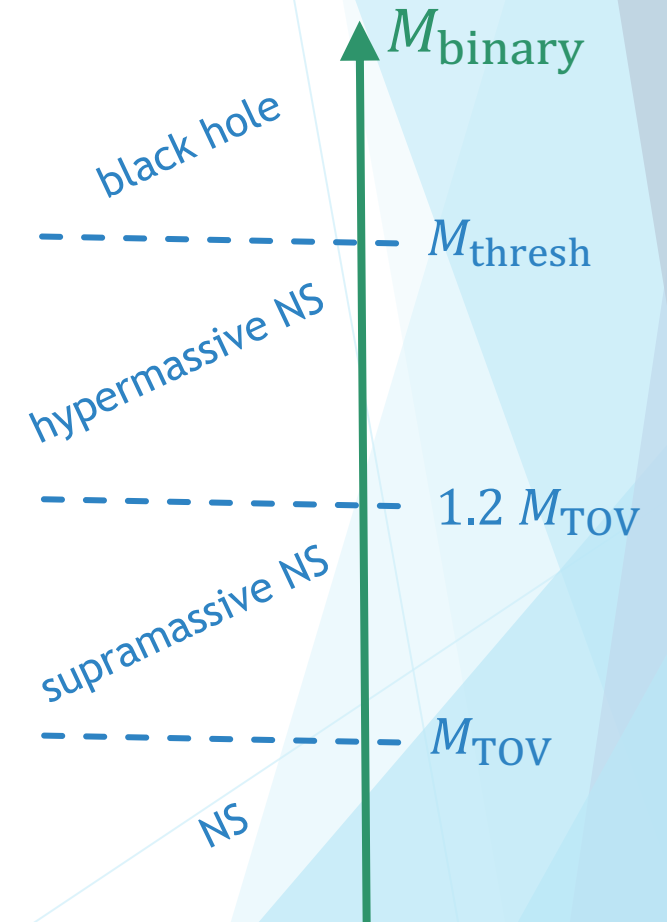
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  - BNS mergers = exclusive progenitors of short GRBs

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  - GRB jet  $\leftrightarrow$  accretion onto BH
    - $\Rightarrow$  merger must form BH quickly

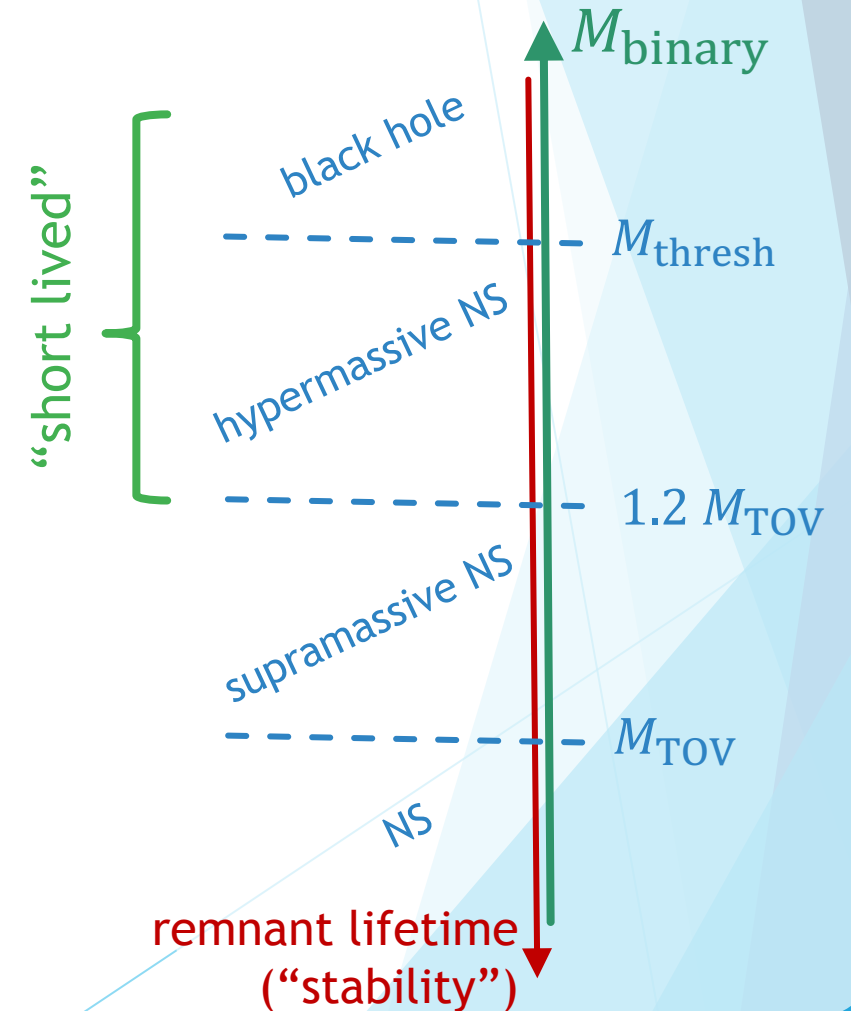
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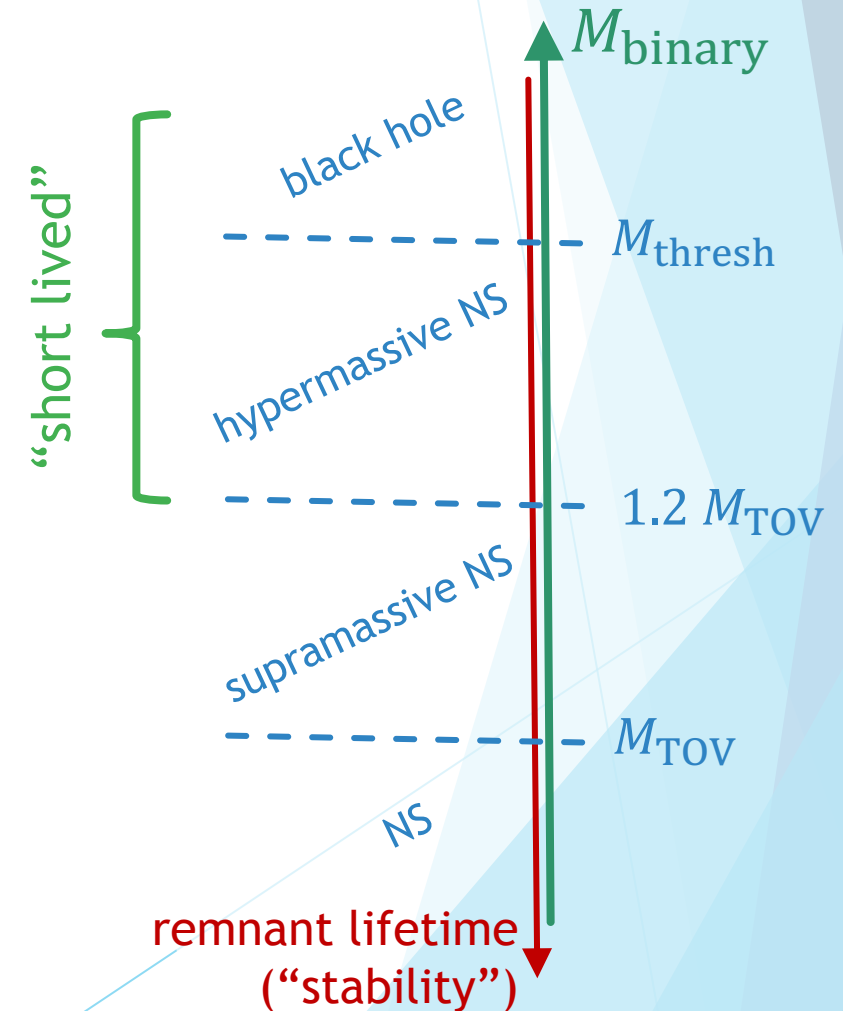
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# EOS constraints from EM counterparts of mergers

Kiziltan et al. (2013)

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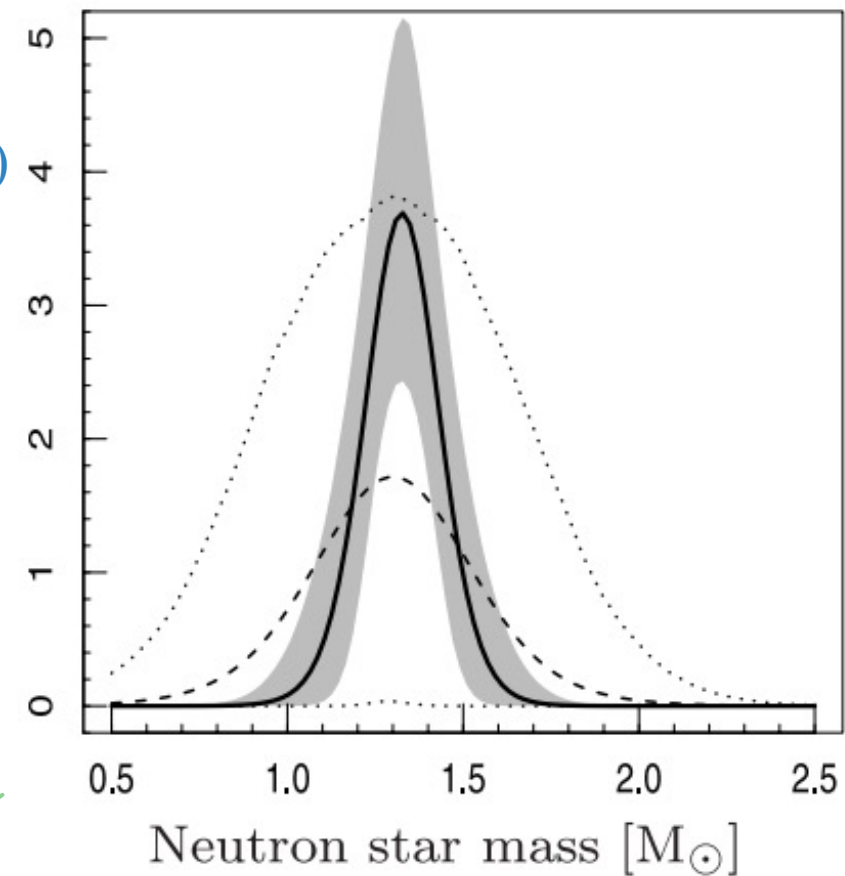
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mass distribution



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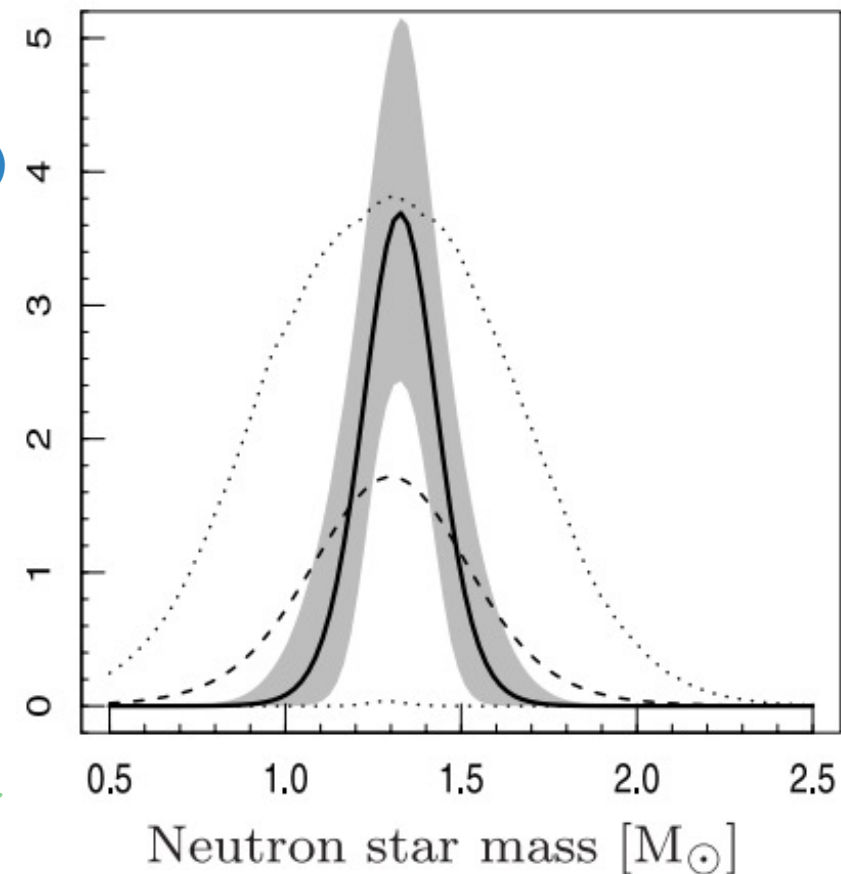
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- then:

$$M_{\text{TOV}} \lesssim 2.2M_{\odot} \quad (\text{Lawrence+15; Fryer+15})$$



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- if  $M_{\text{binary}} \lesssim 1.2M_{\text{TOV}}$  :
  - bright radio emission at late times

$\left[ \begin{array}{l} \sim 10^{53} \text{erg of remnant's} \\ \text{rotational energy should be} \\ \text{injected into surroundings} \end{array} \right]$

(Nakar&Piran11; Margalit&Piran15,20; Hotokezaka&Piran15; ...)

## GRB Radio Follow-up:

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constrains this scenario

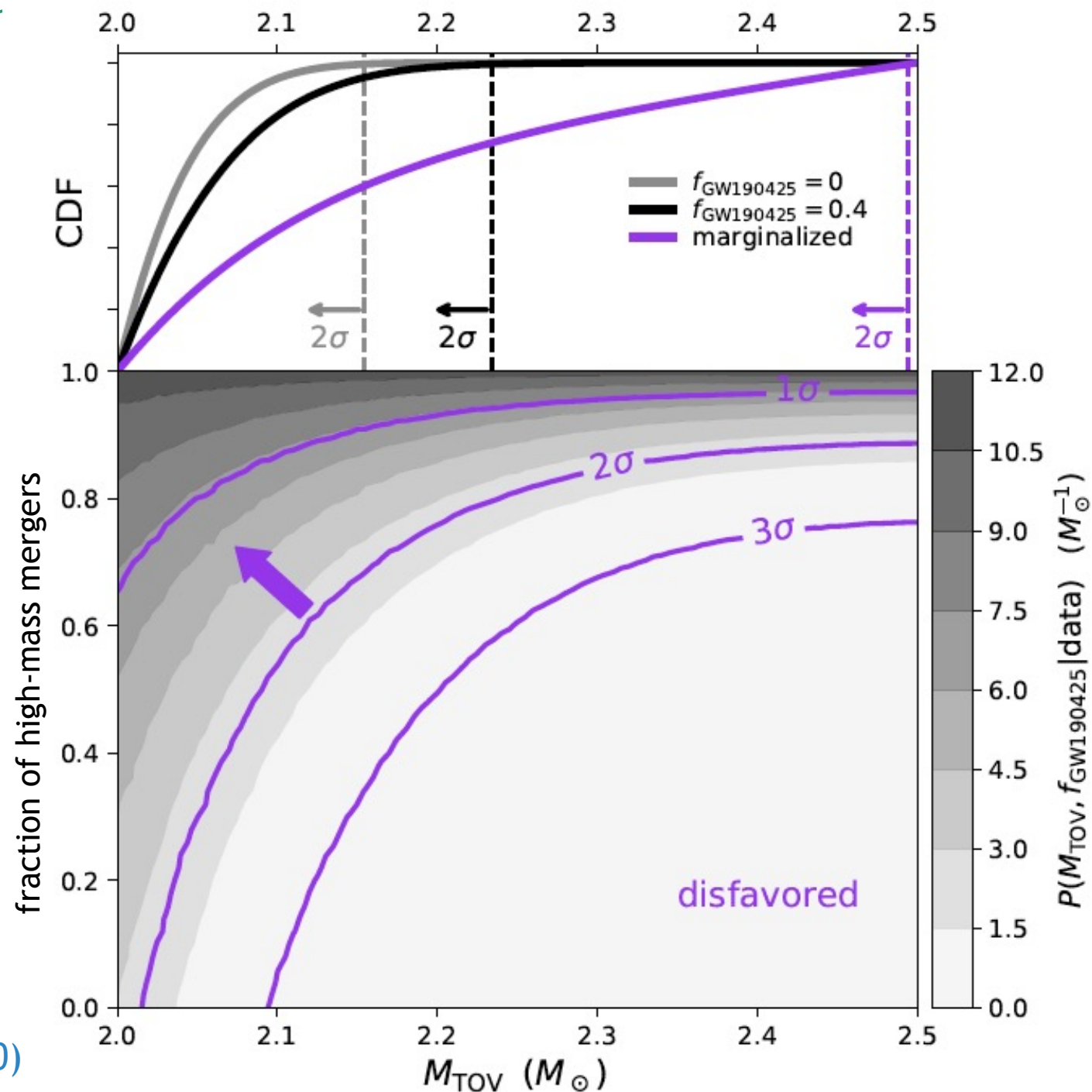
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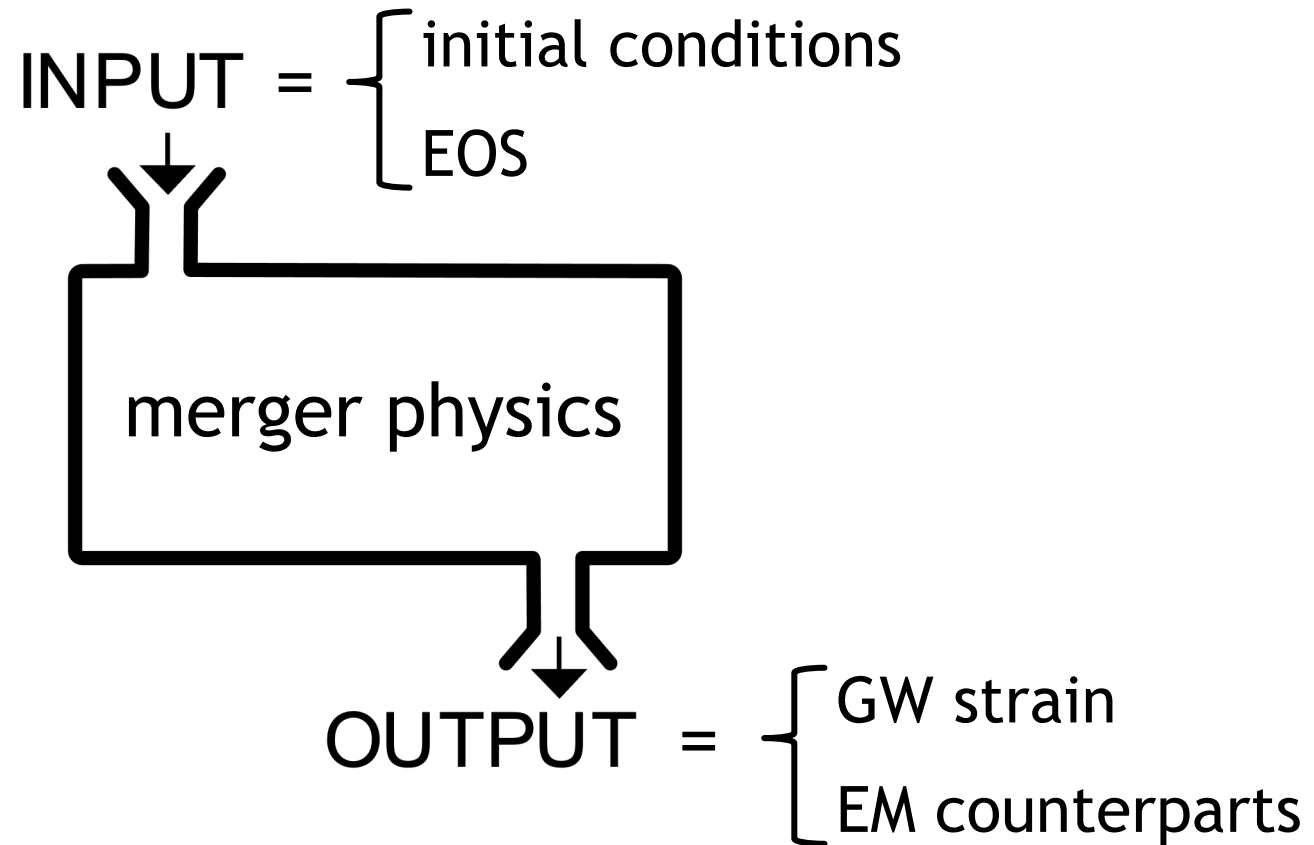
Schroeder, BM et al. (2020)



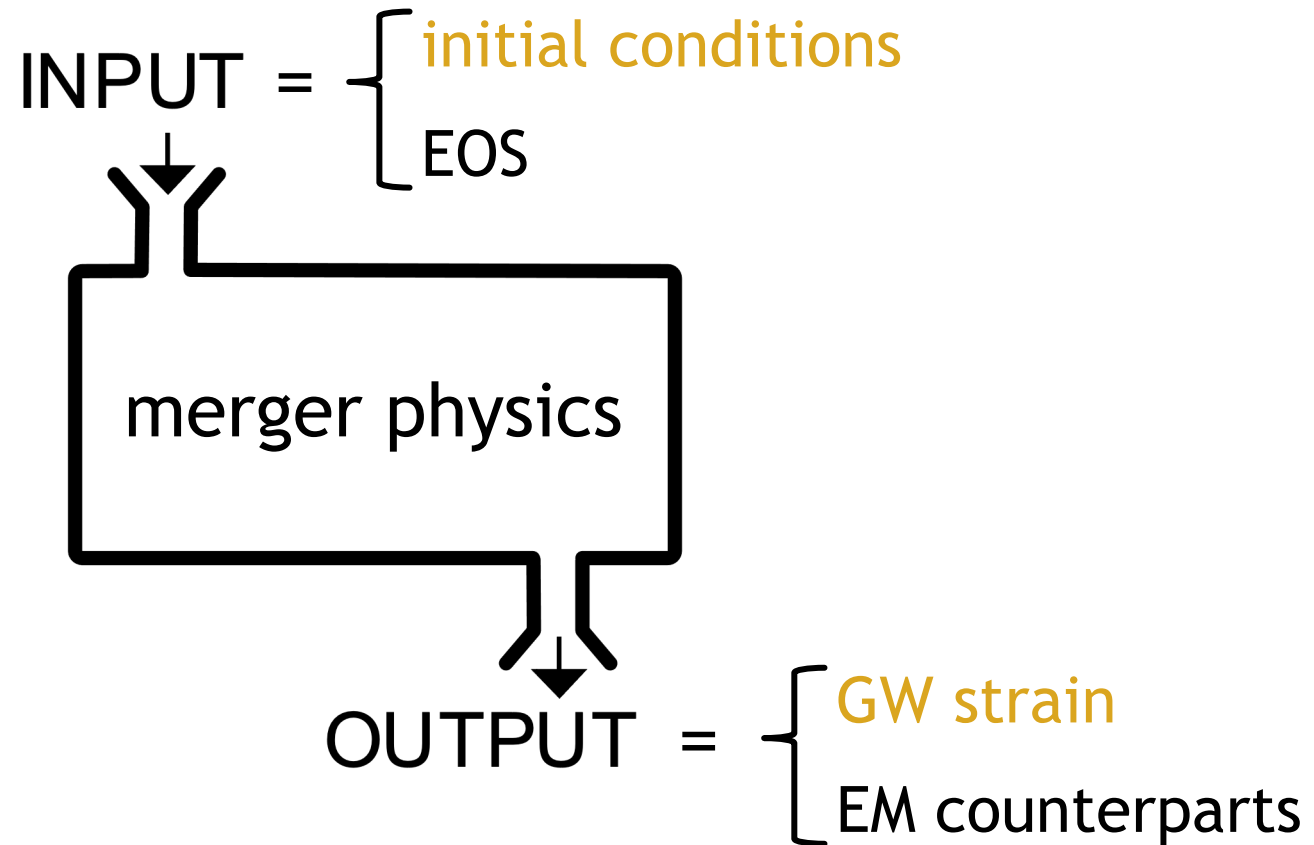
Multi-Messenger Constraints:



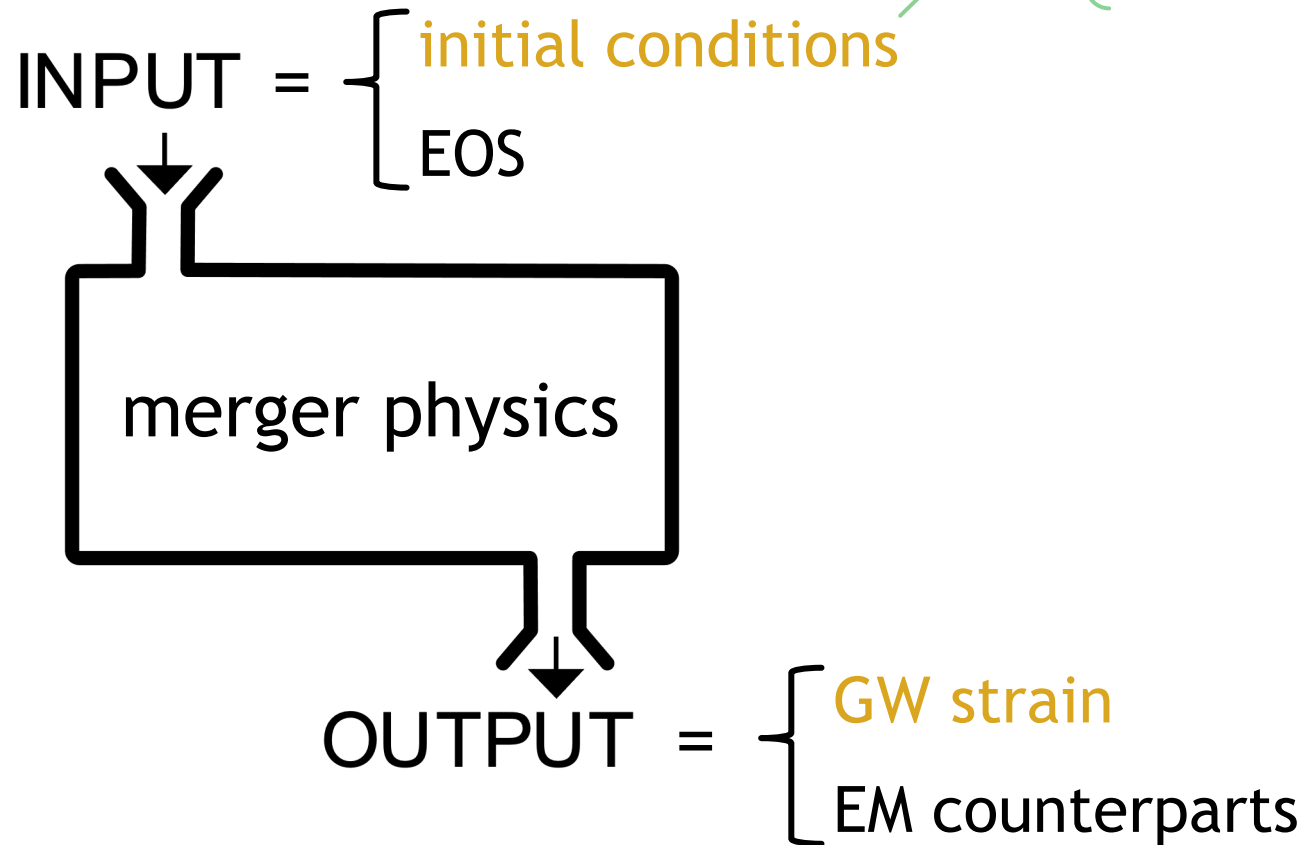
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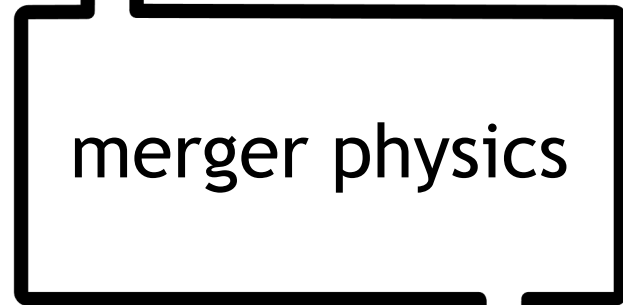


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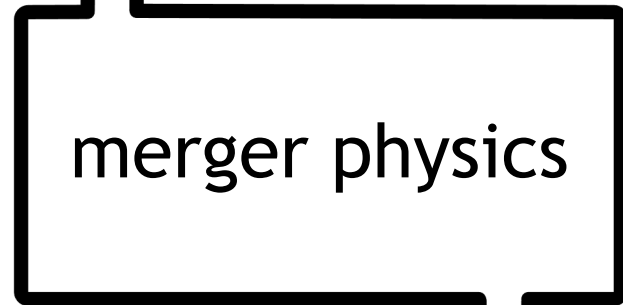
OUTPUT = { GW strain  
EM counterparts

binary parameters:  
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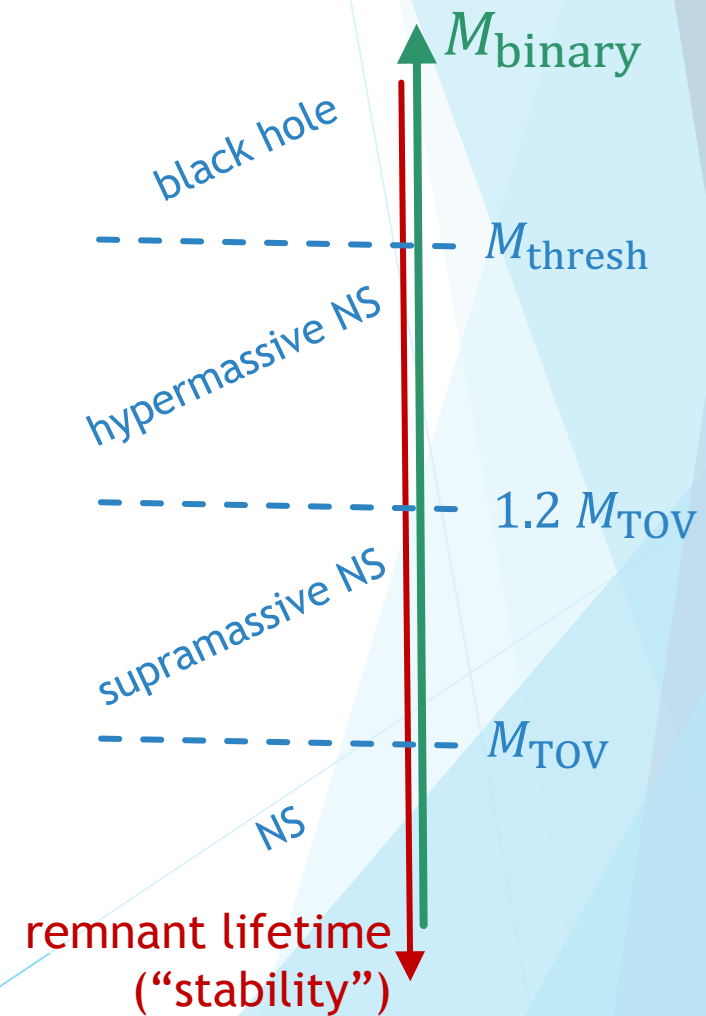
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GW

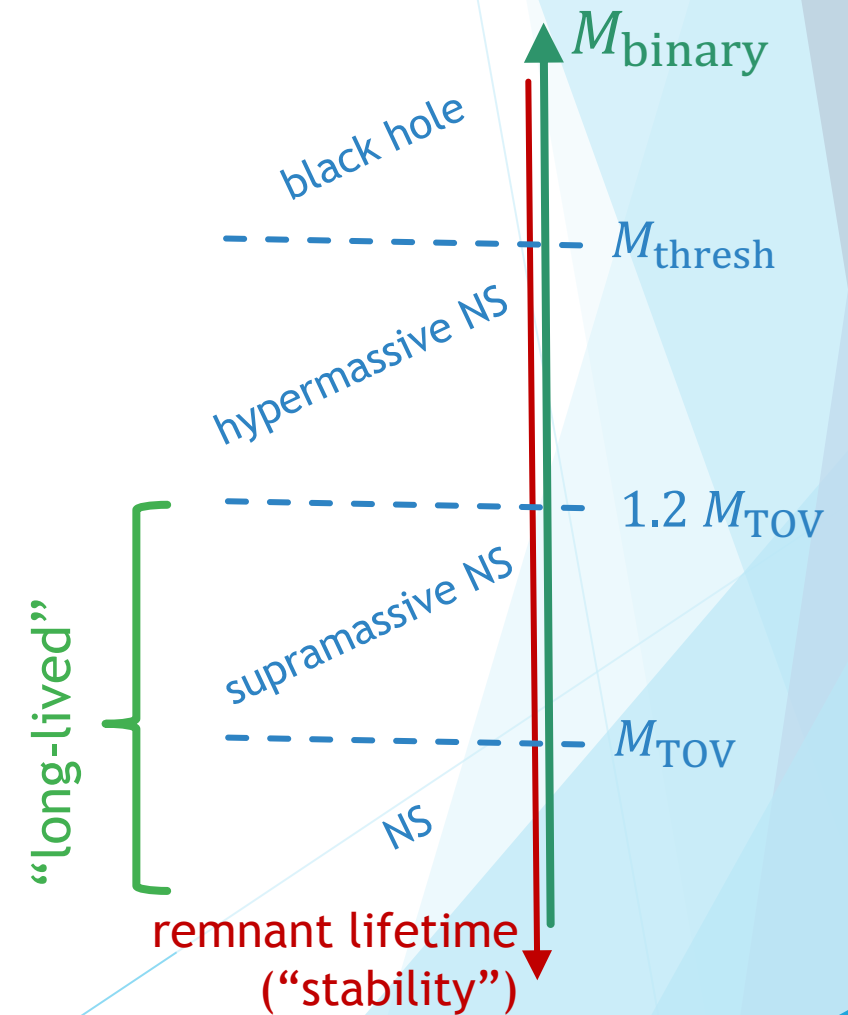
no need for assumptions  
about mass distribution

## GW170817:



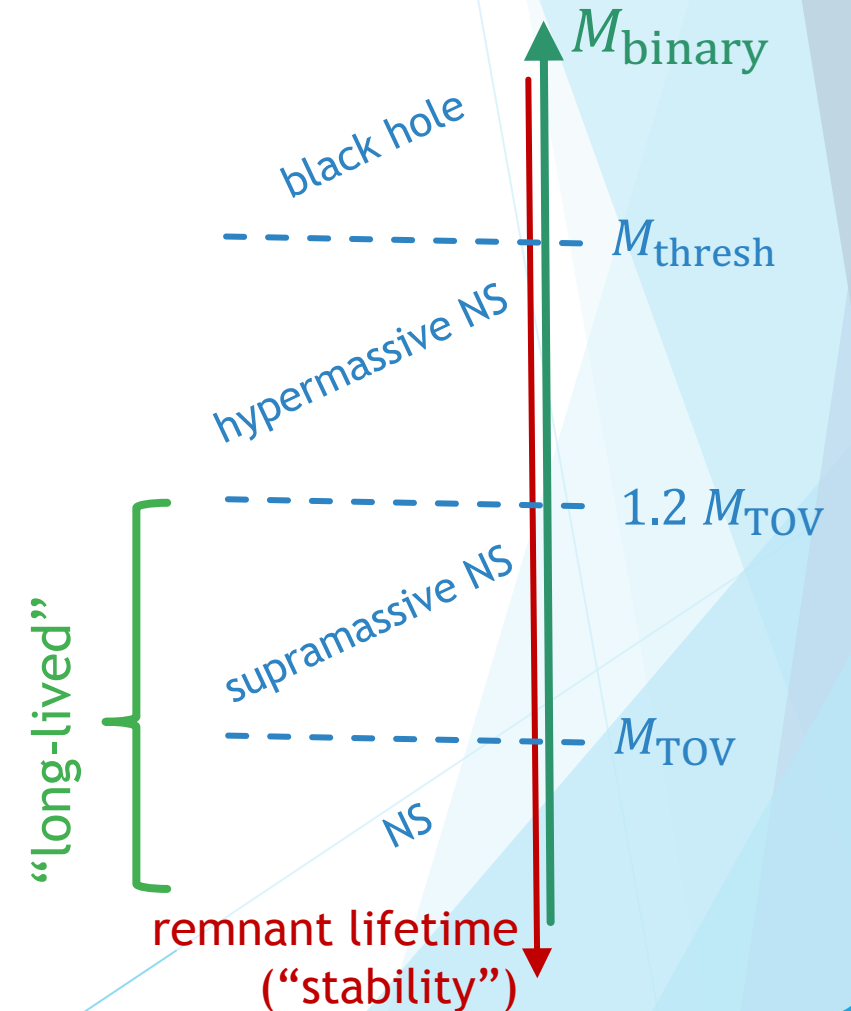
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- rule out long-lived remnant



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  - energetics  
(Margalit&Metzger17)
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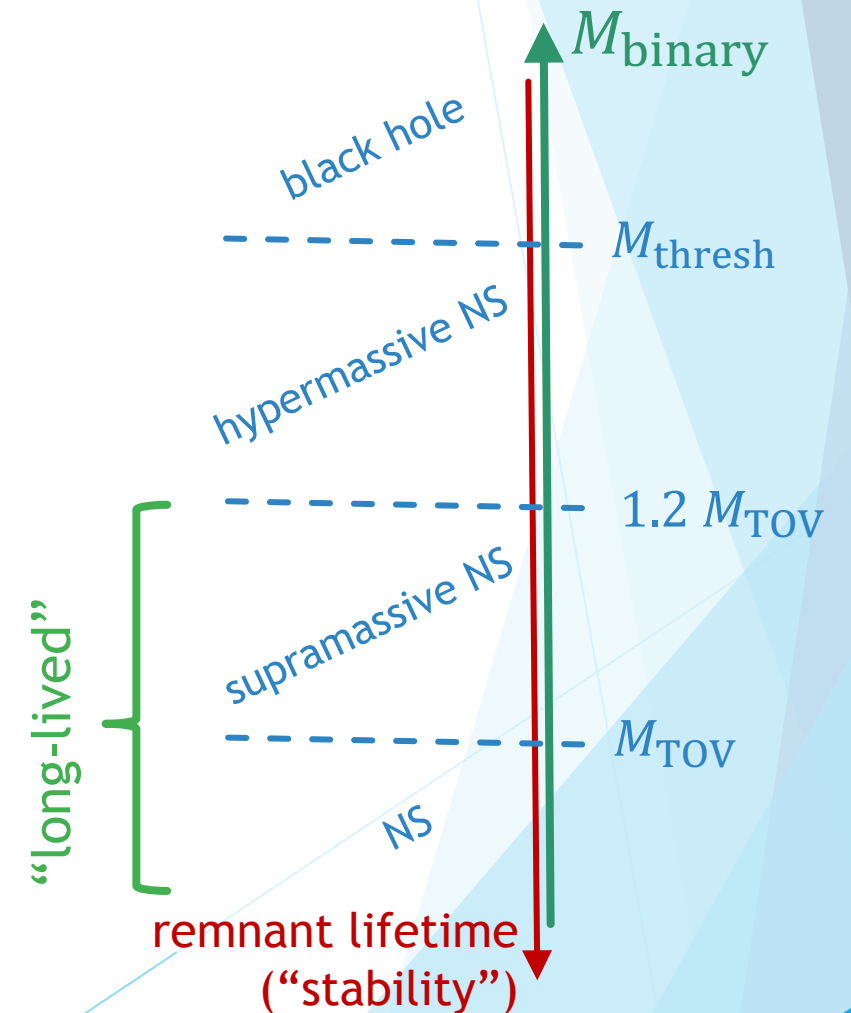


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$$\Rightarrow M_{\text{TOV}} \lesssim 2.2 M_{\odot}$$

(BM&Metzger17; ...; Shibata+19)



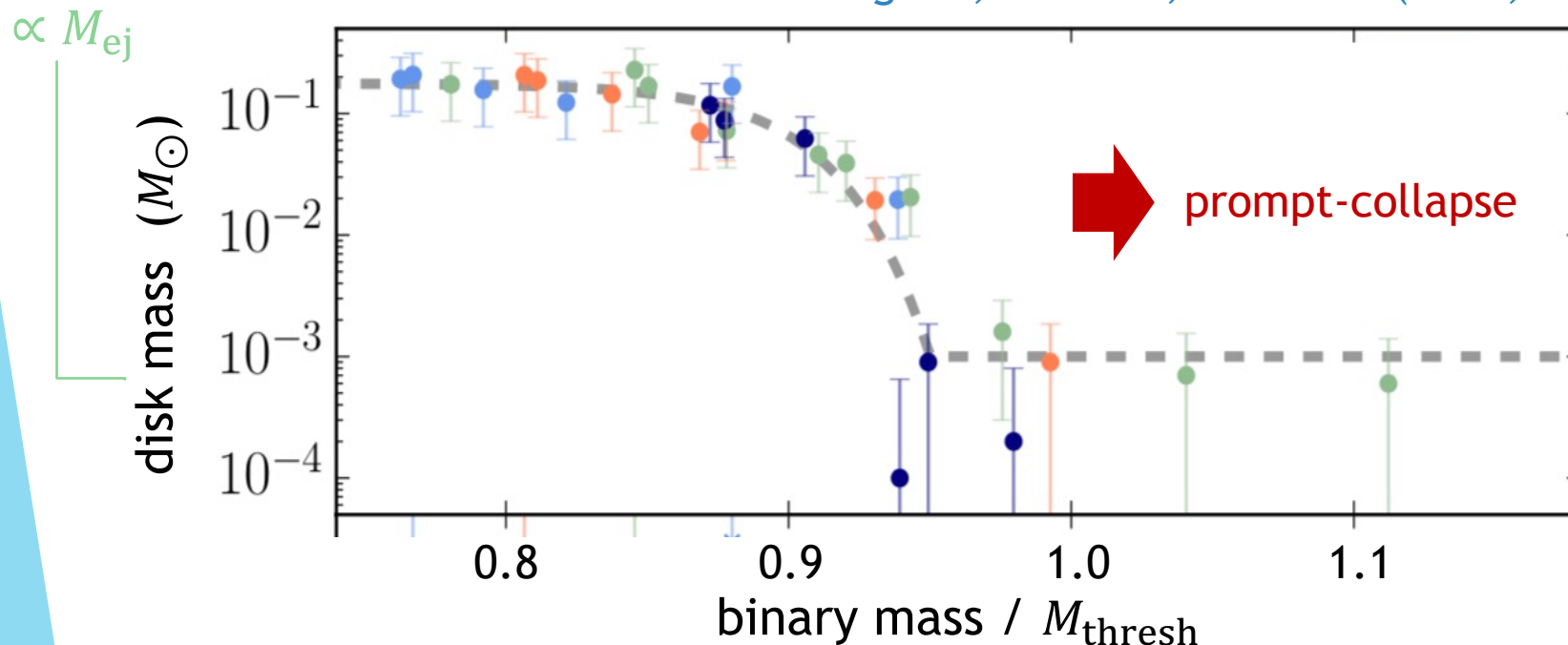
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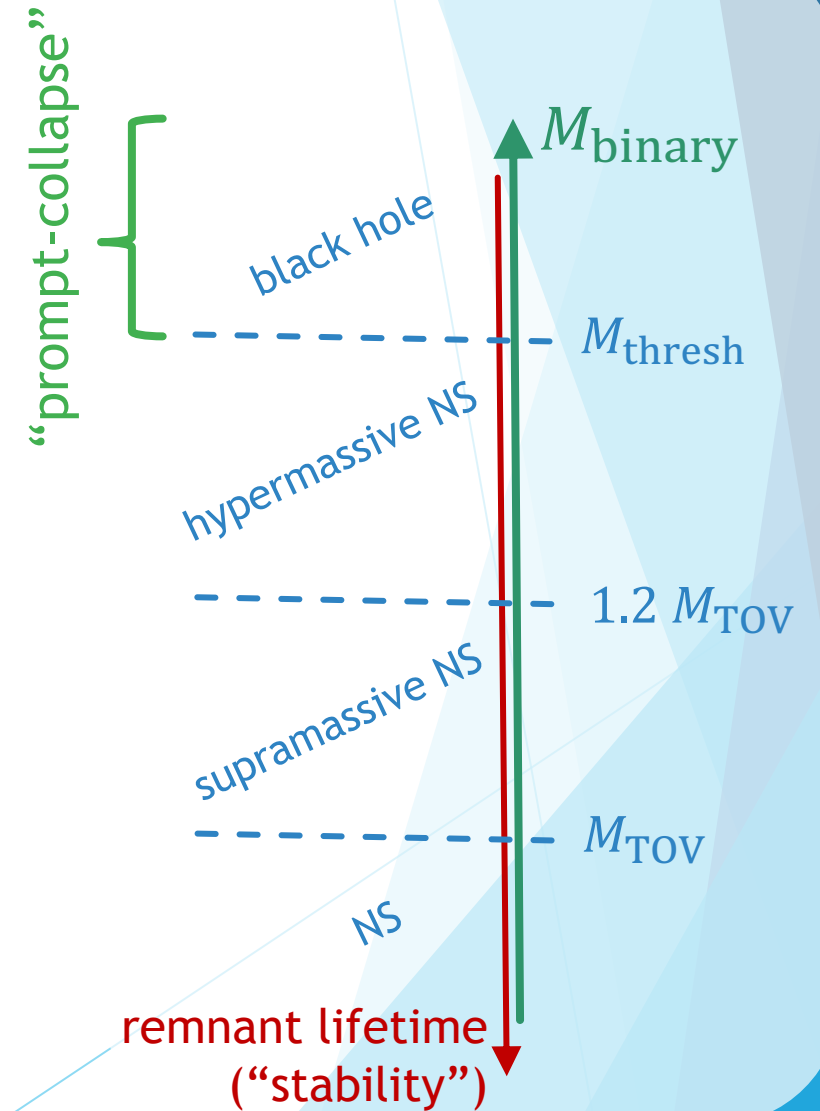
- rule out prompt-collapse
- main argument: **ejecta mass**

Coughlin, Dietrich, BM et al. (2019; see also Radice+18)



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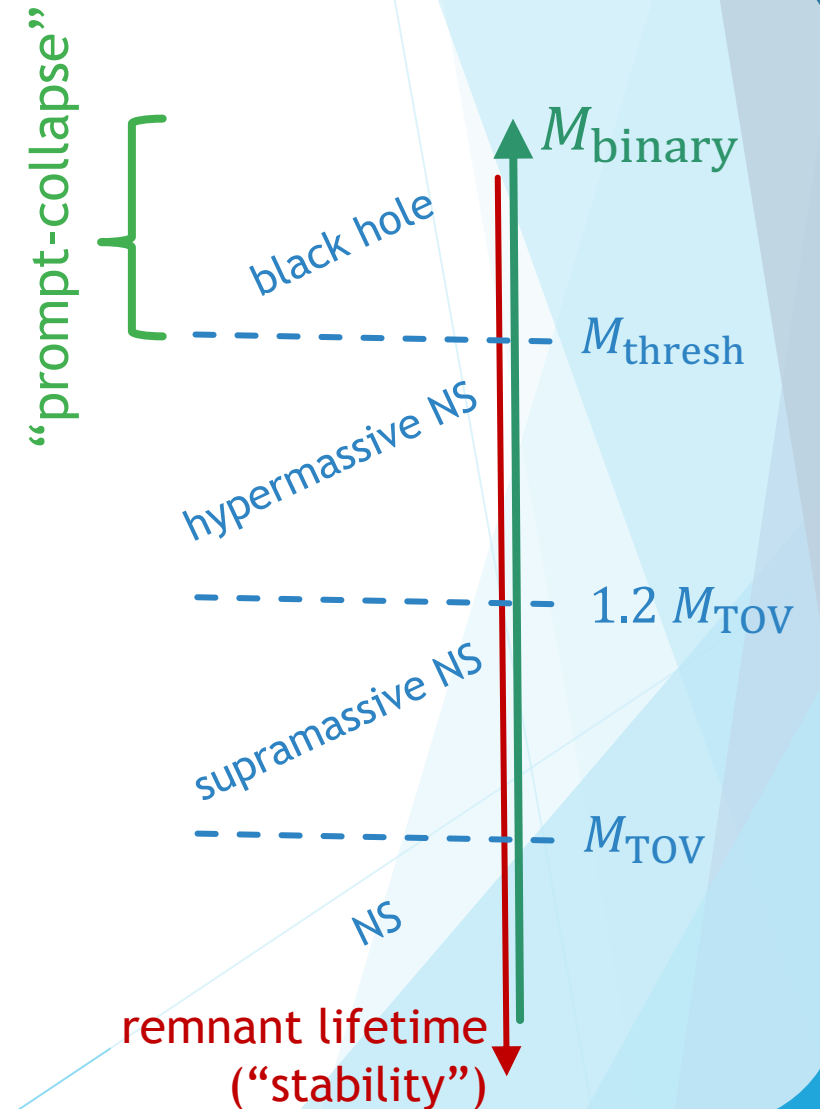
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$$\Rightarrow M_{\text{thresh}}(M_{\text{TOV}}, R_{1.6}) > M_{170817}$$



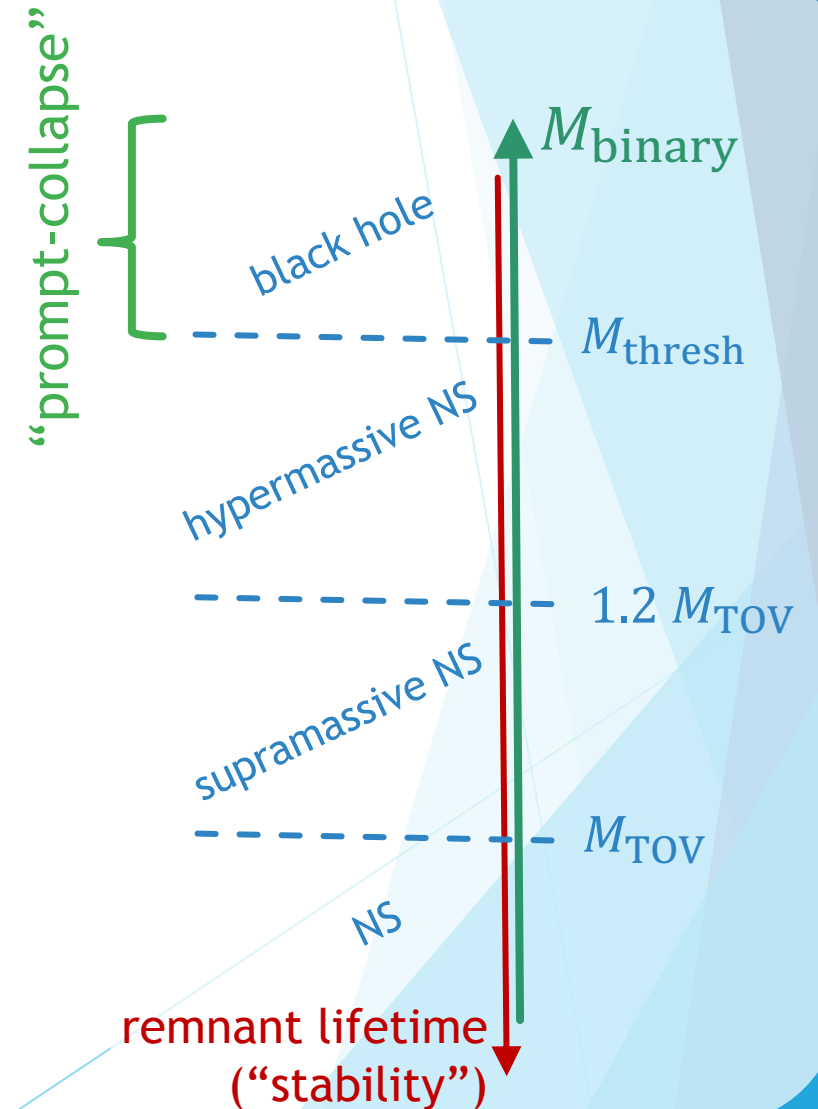
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$$\Rightarrow M_{\text{thresh}}(M_{\text{TOV}}, R_{1.6}) > M_{170817}$$

$$\Rightarrow R_{1.6} > 10.3 \text{ km}$$

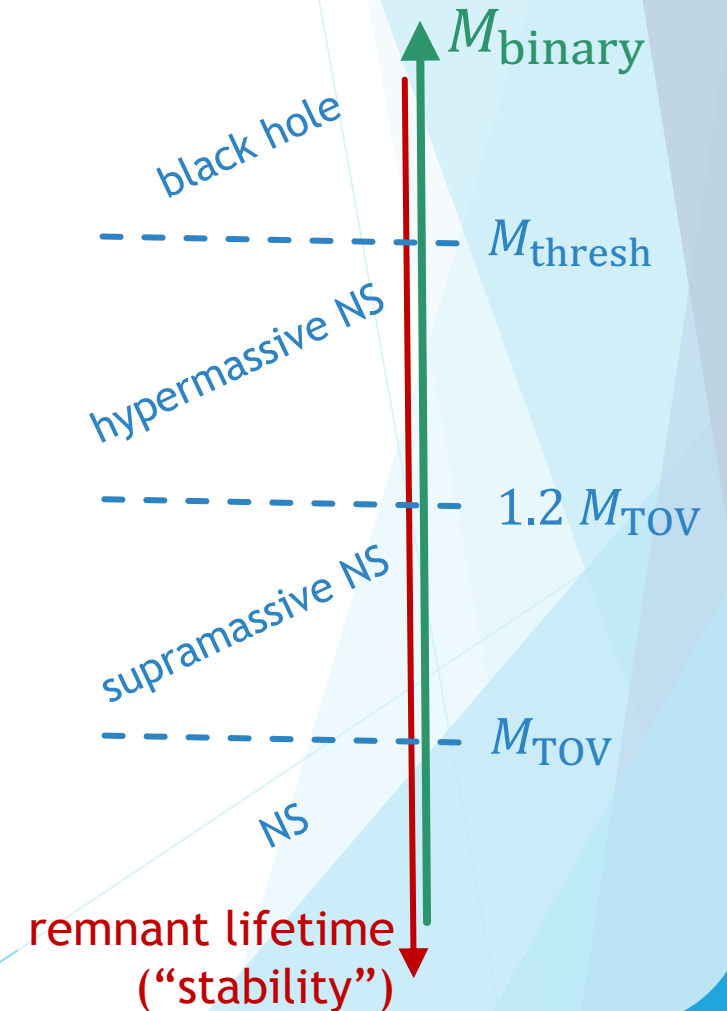
(Bauswein+17; Radice+18; Capano,...,BM+20; though see Kiuchi+19)



## GW170817:

- quantitative fitting of numerical relativity results & kilonova modeling to observed counterpart

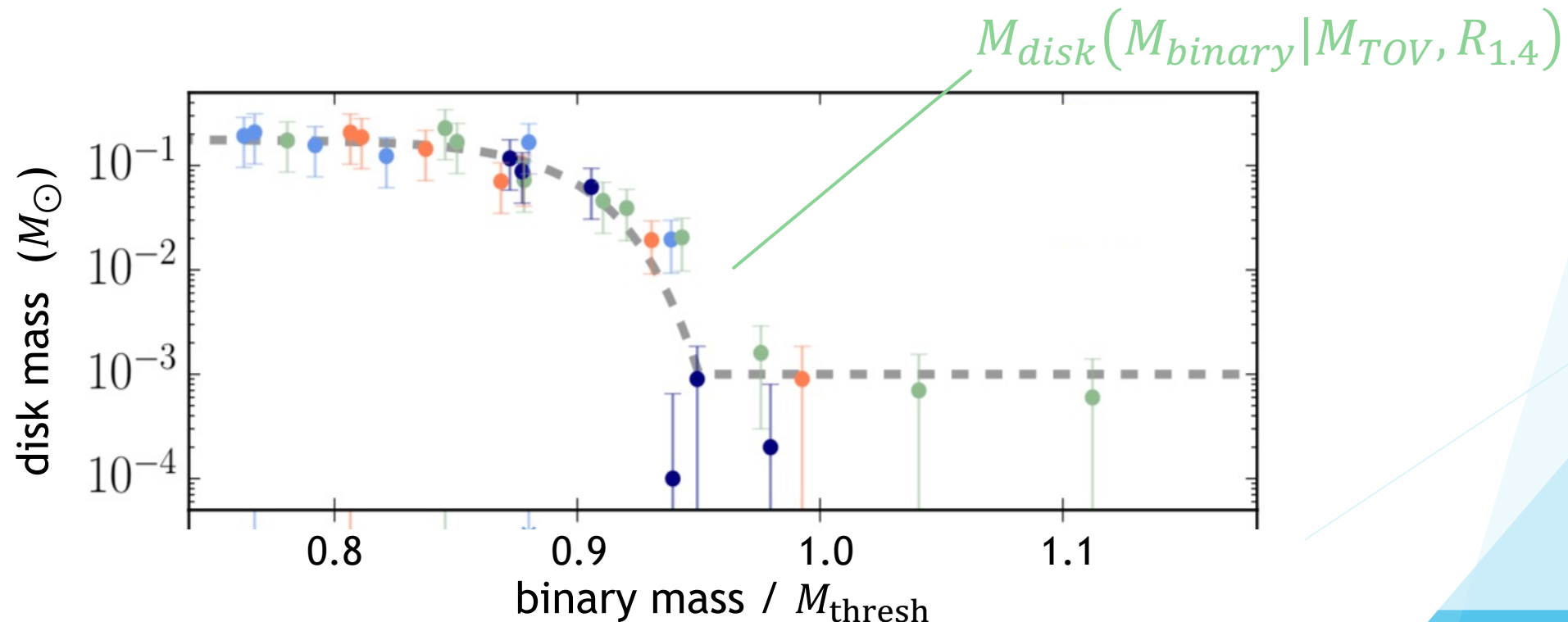
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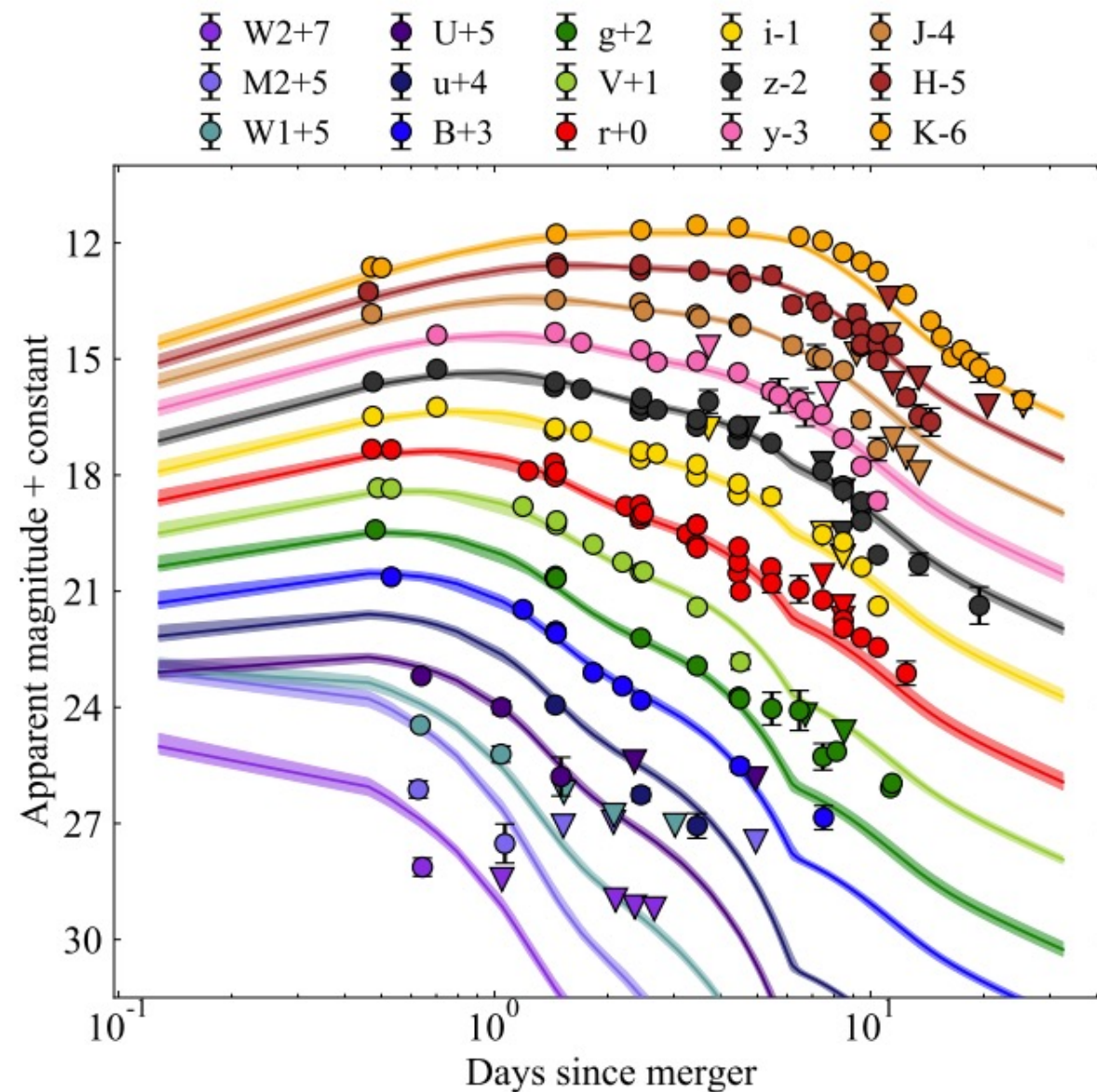


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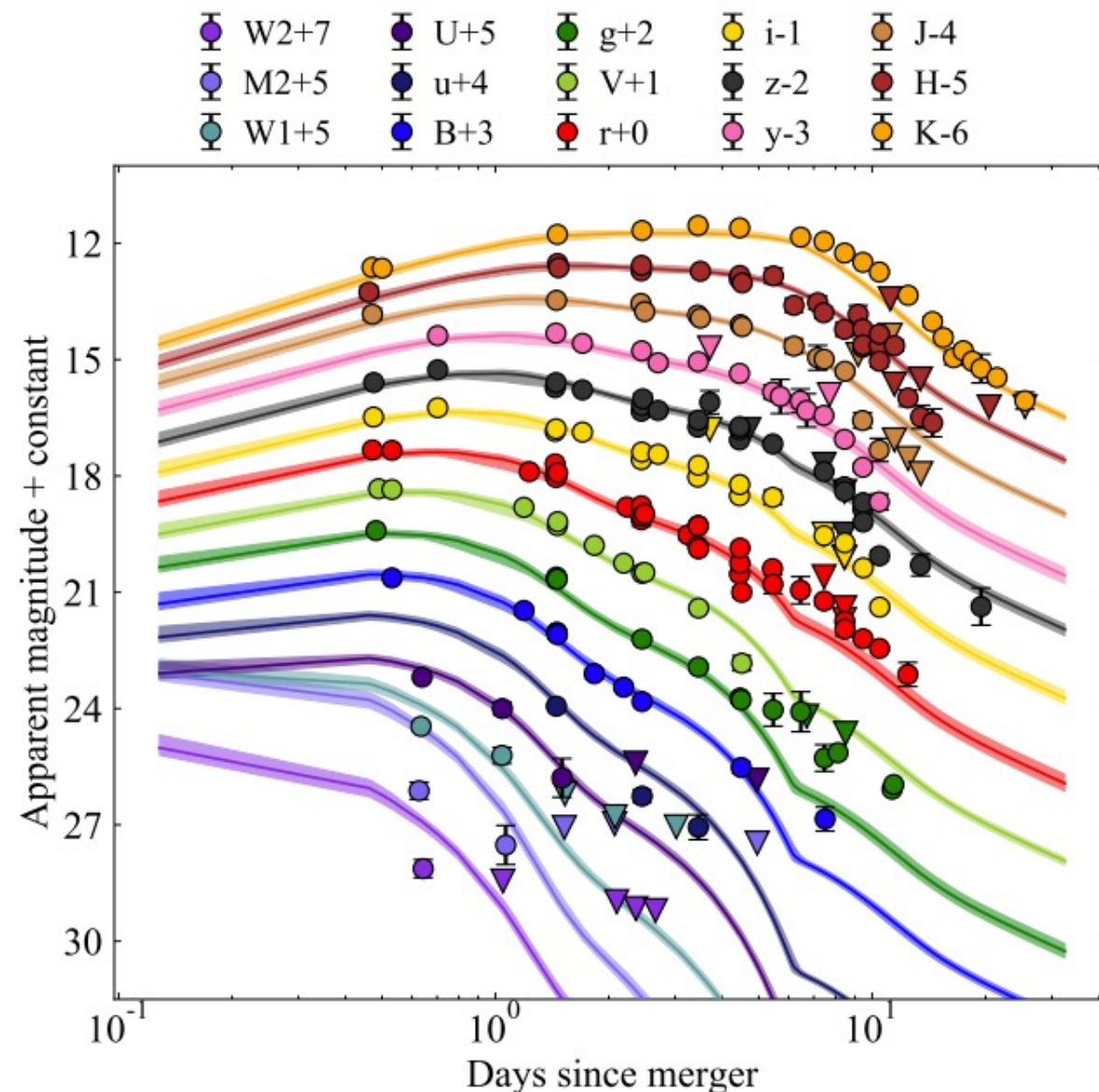
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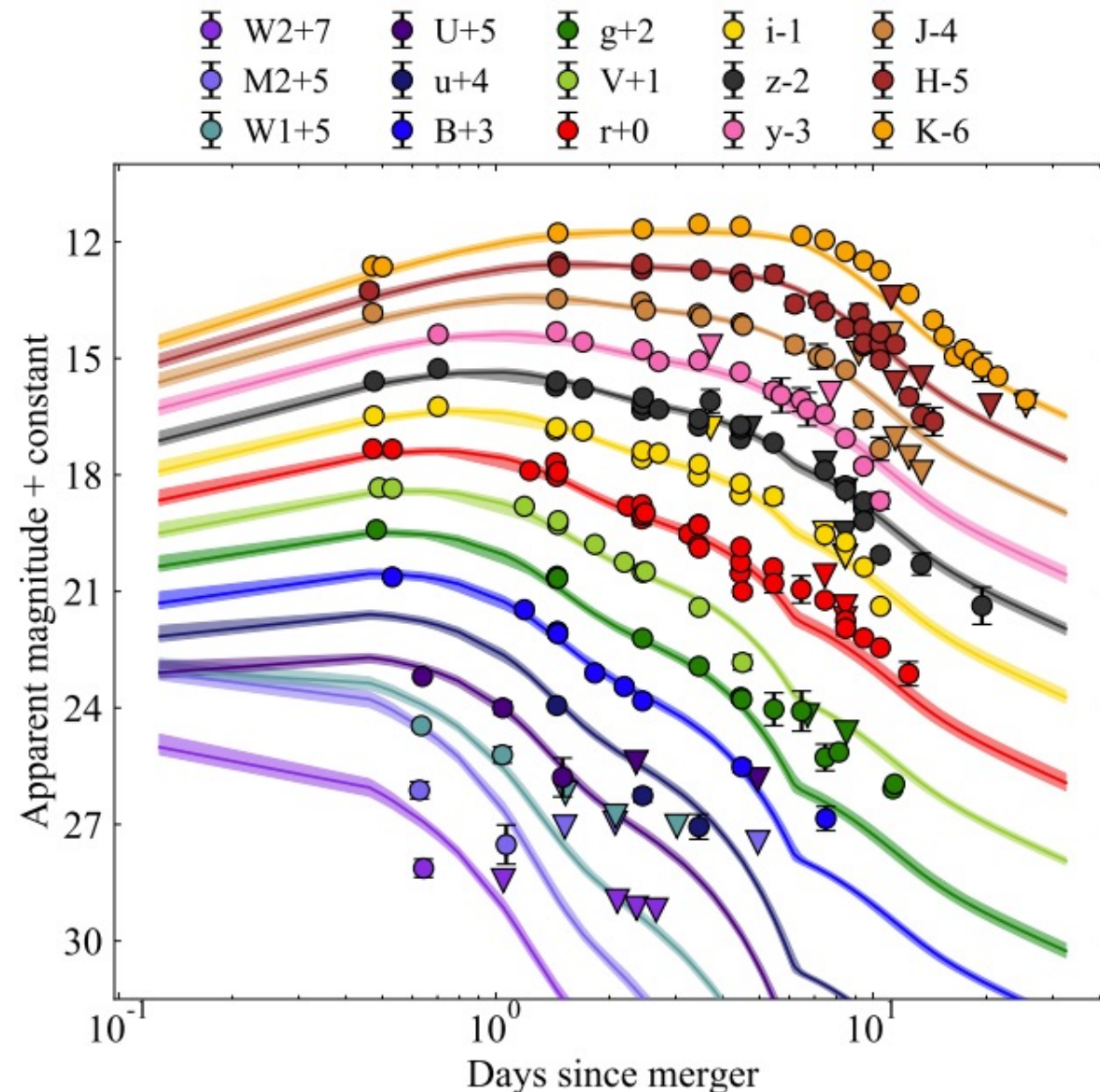
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$$M_{red}(M_{binary}, q | M_{TOV}, R_{1.4})$$

$$v_{red}(\dots)$$

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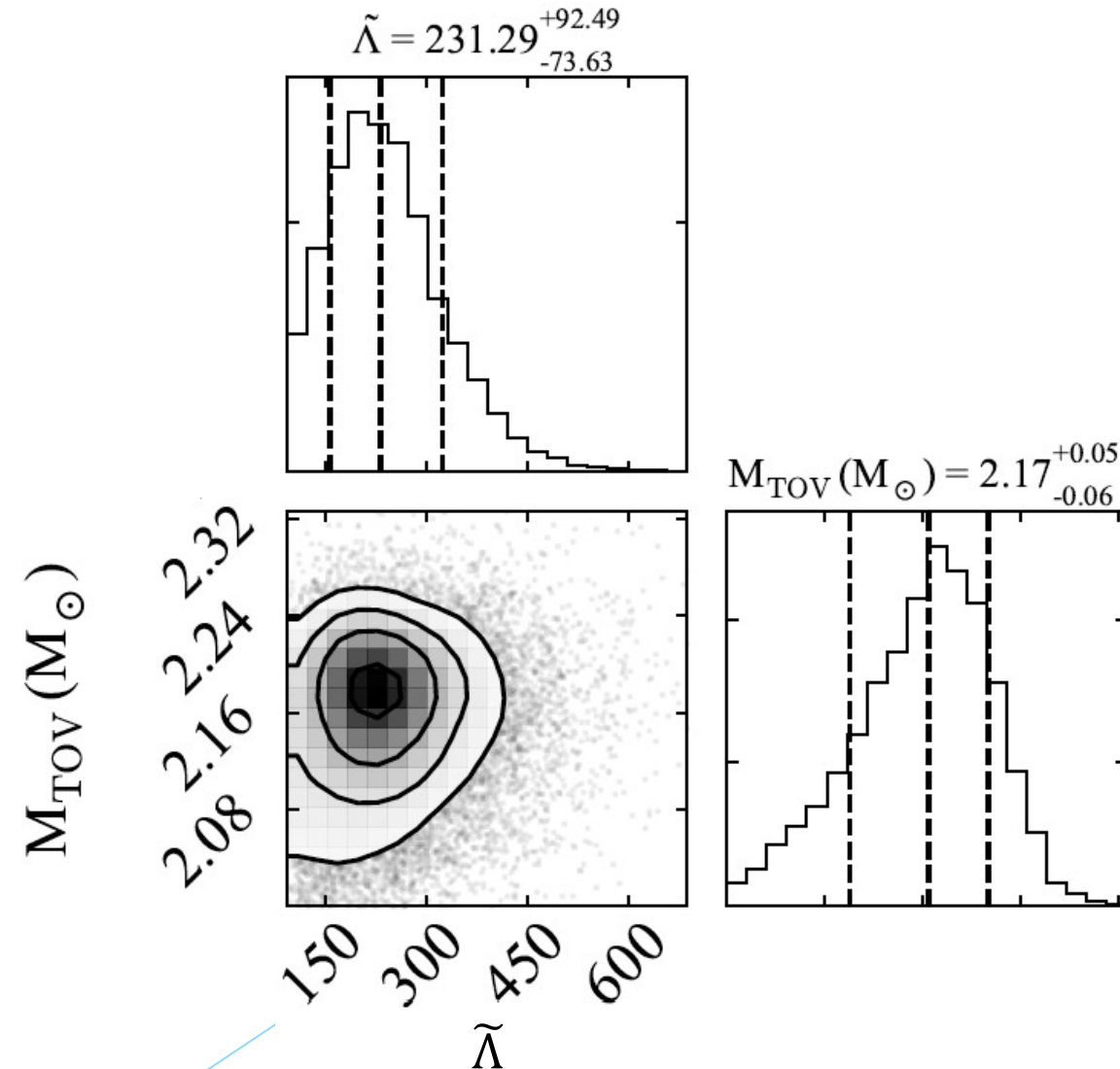
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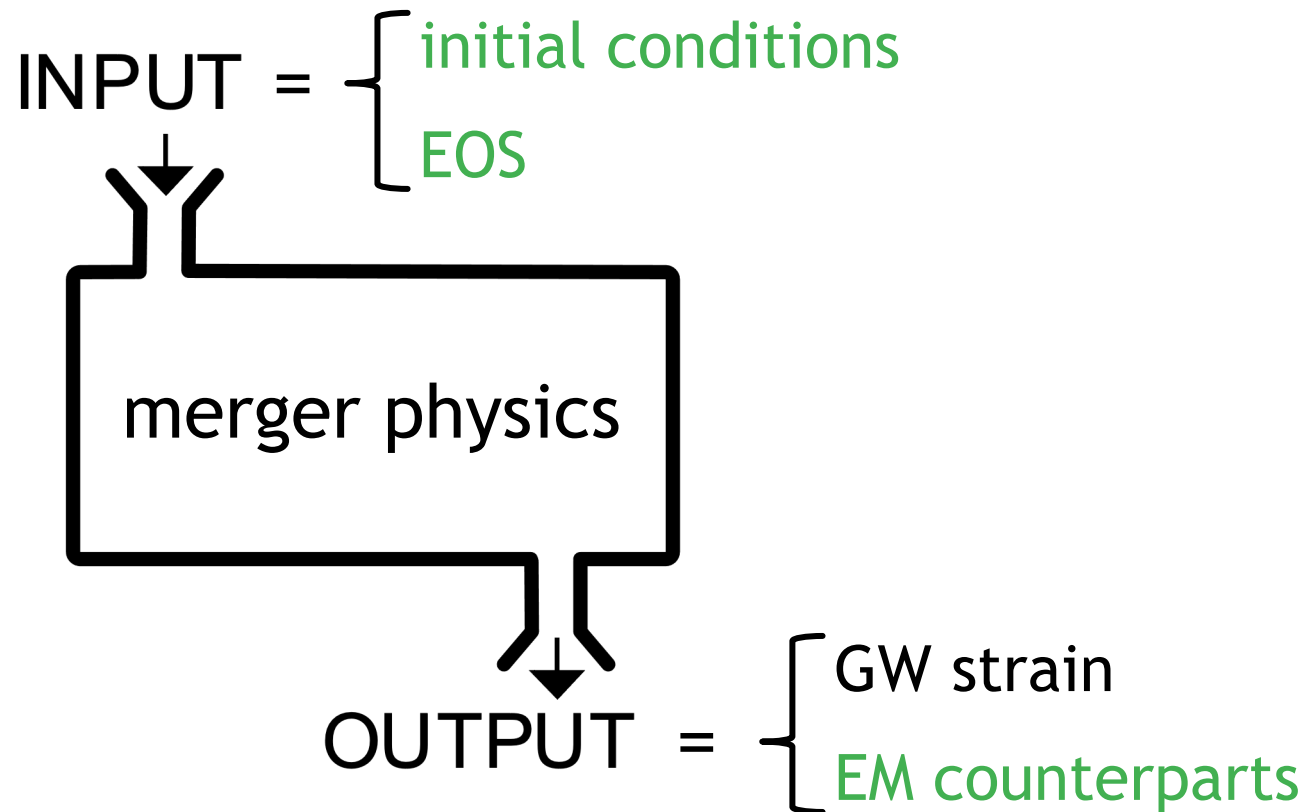
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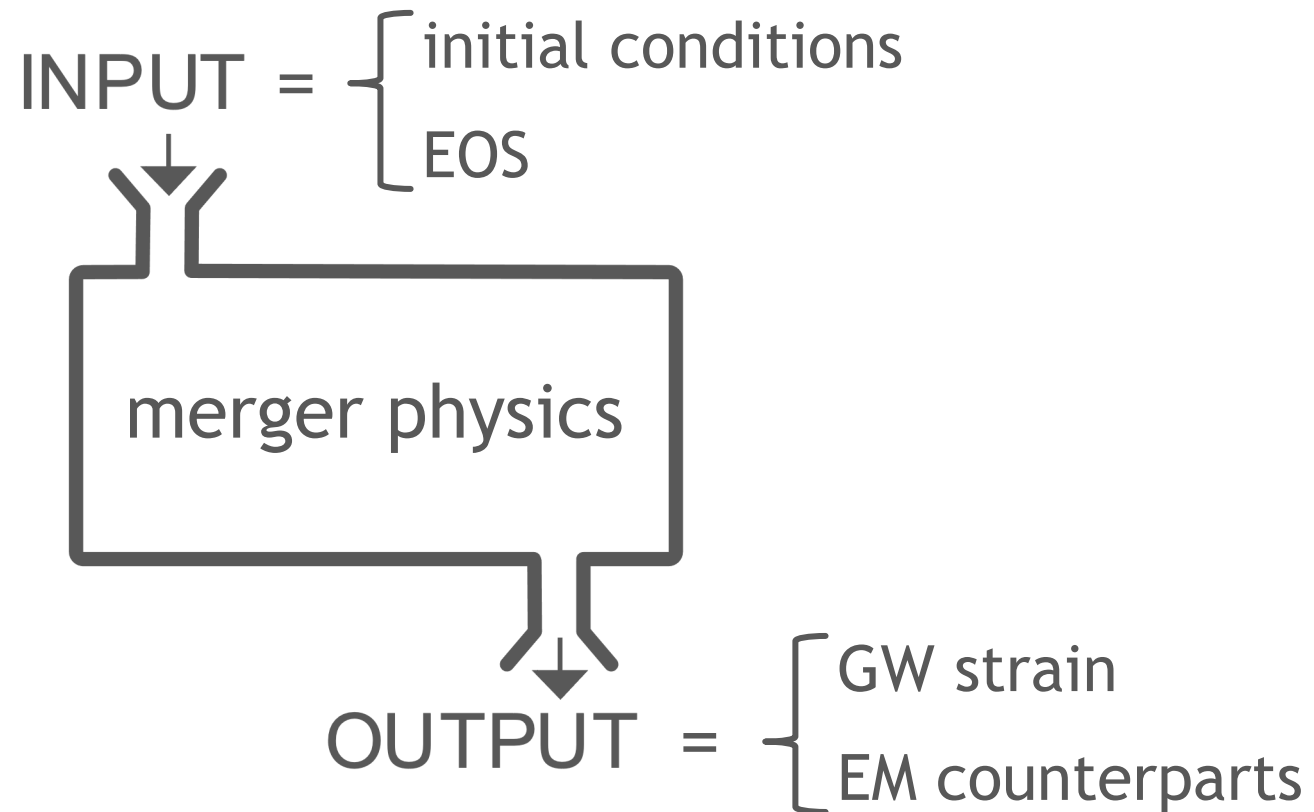


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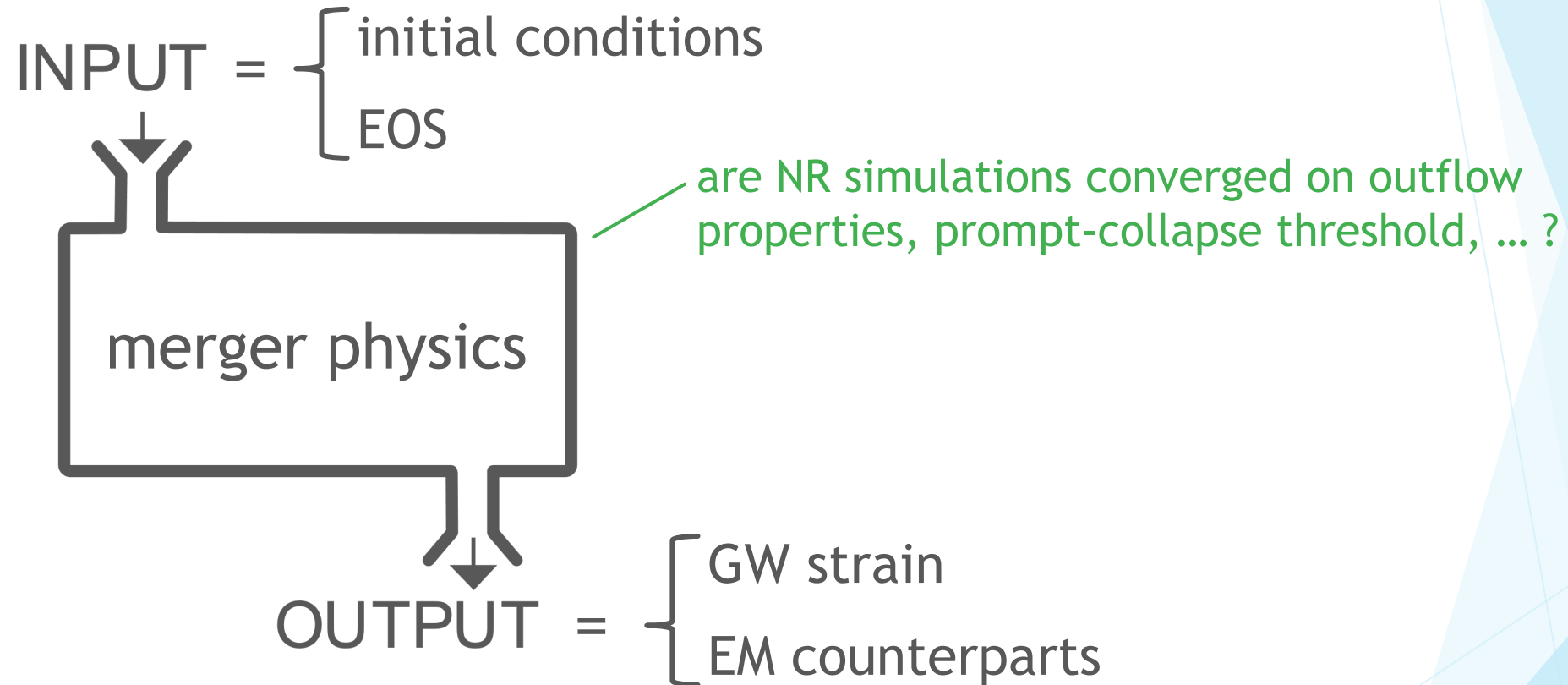


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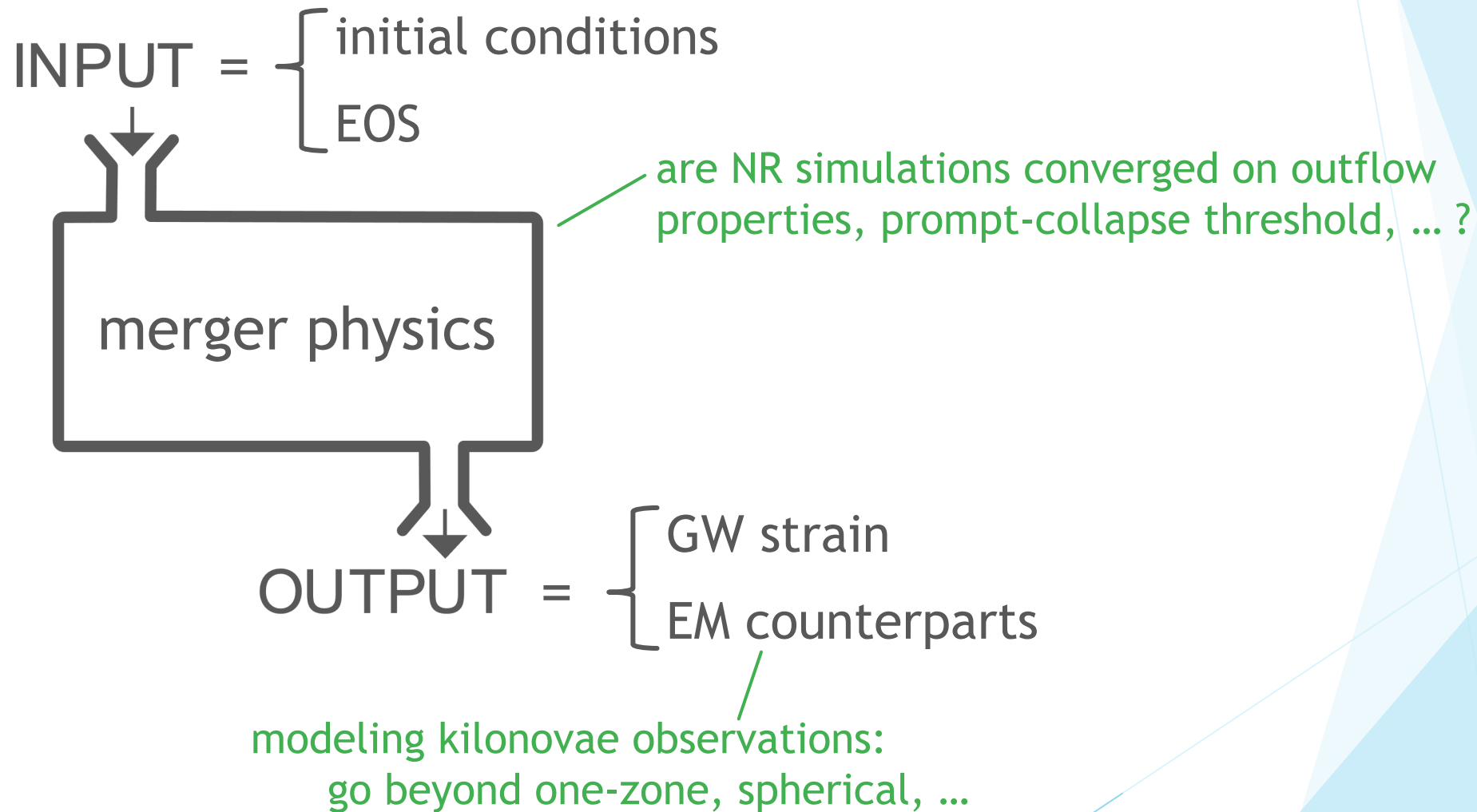
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