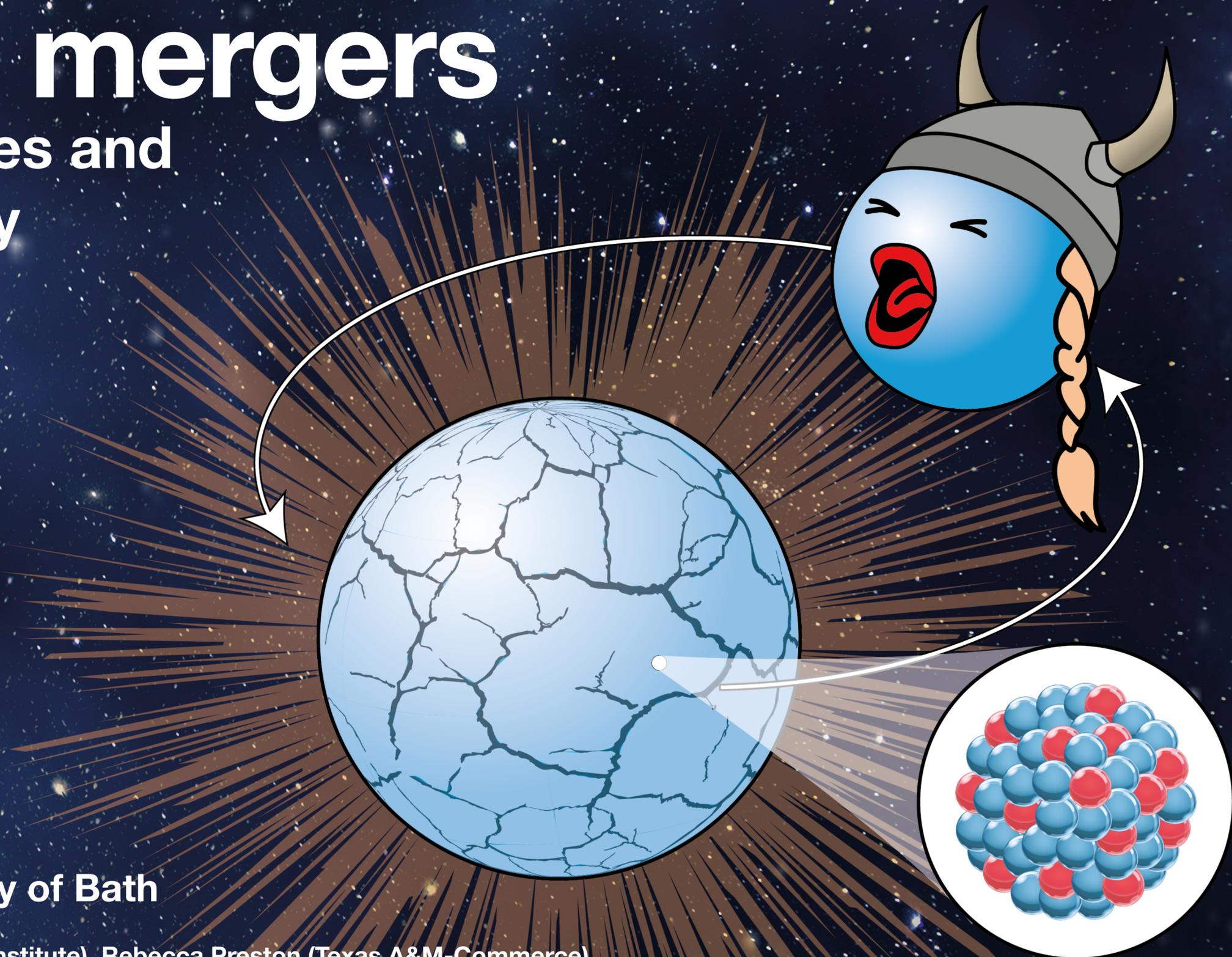


# Probing nuclear physics with neutron star mergers

Resonant shattering flares and  
nuclear symmetry energy

ECT\* Workshop, Jun 20, 2022



**David Tsang, Duncan Neill, University of Bath**

With Will Newton (Texas A&M-Commerce),

Hendrik Van Eerten (U. Bath), Geoffery Ryan (Perimeter Institute), Rebecca Preston (Texas A&M-Commerce)

# Why are neutron stars important to nuclear physicists?

Which regions of a neutron star tell us about which physics?

What multi-messenger observables can we use?

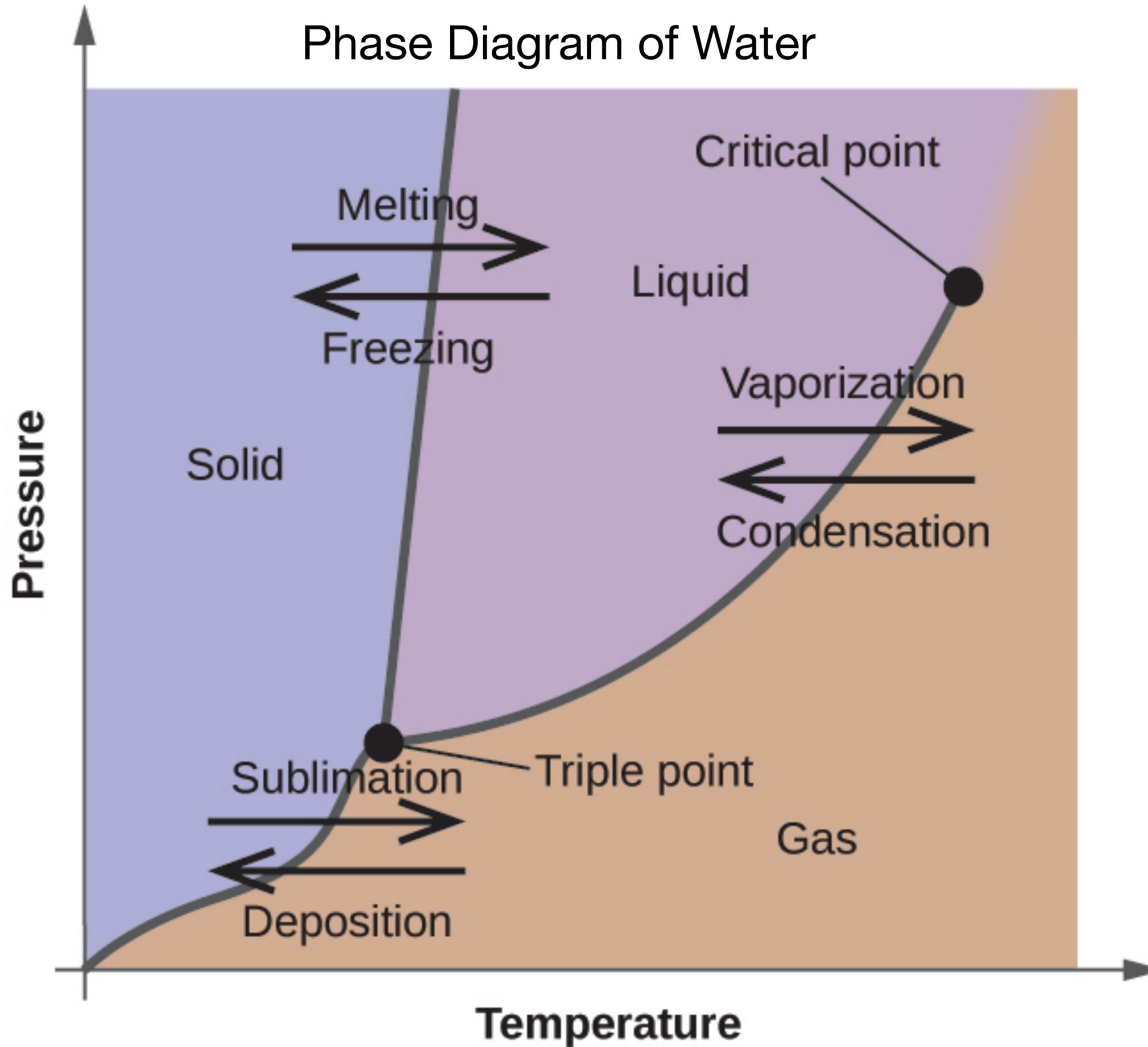
## What are Resonant Shattering Flares (RSFs)?

How can we use RSFs to constrain nuclear physics?

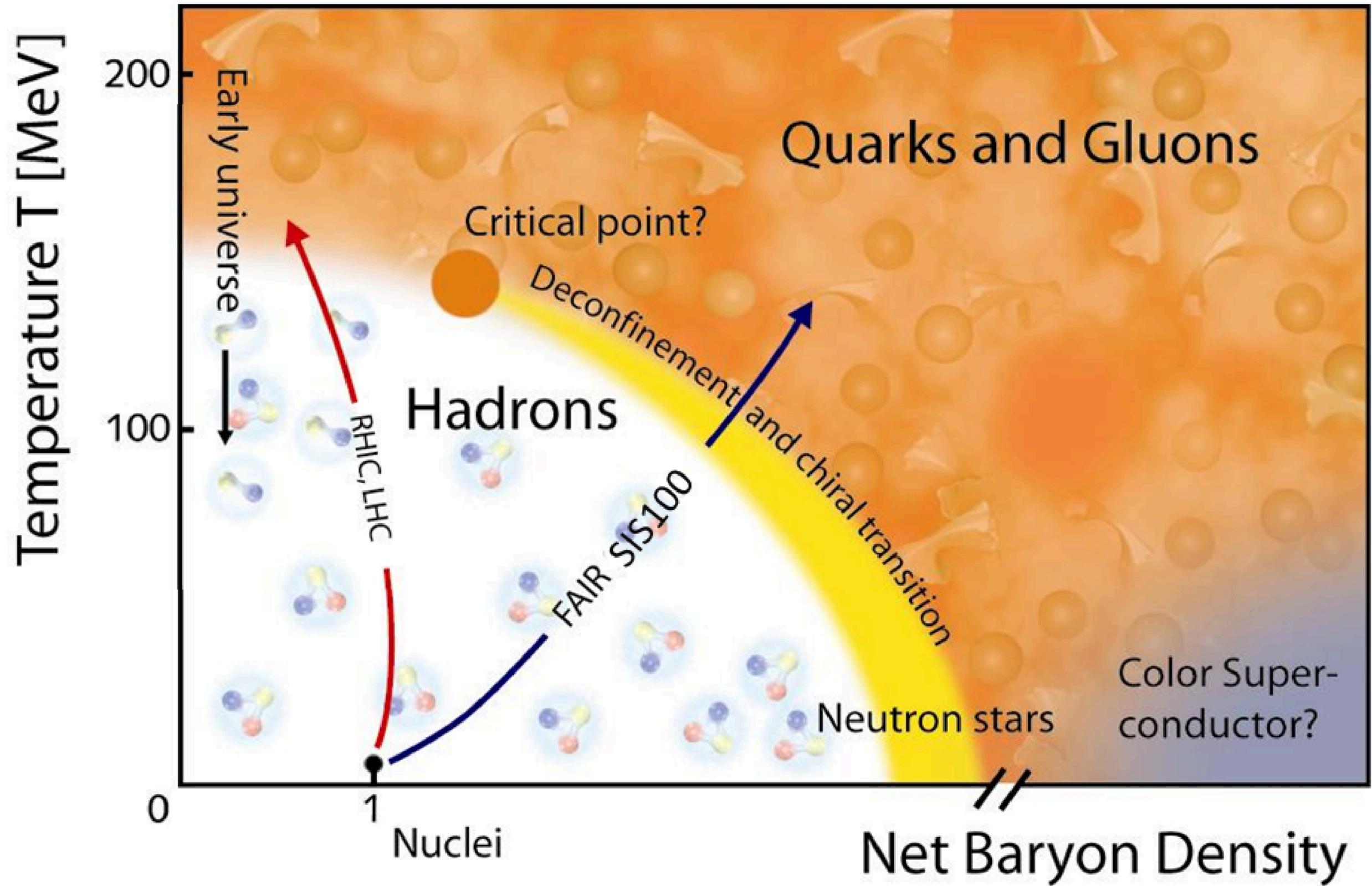
How do RSFs compare to collider experiments?

What are the prospects for detecting RSFs?

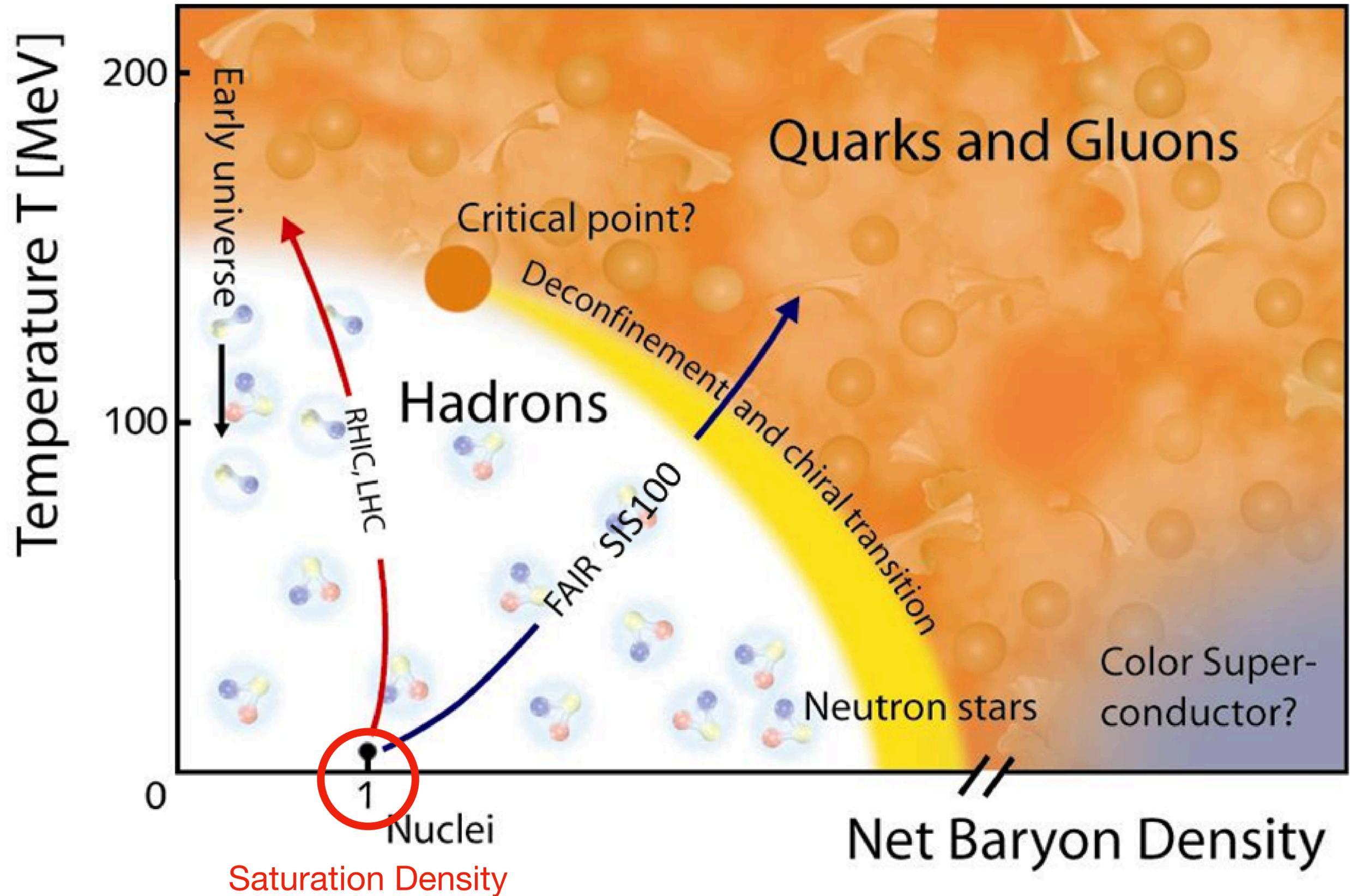
# Phase Diagram of Water



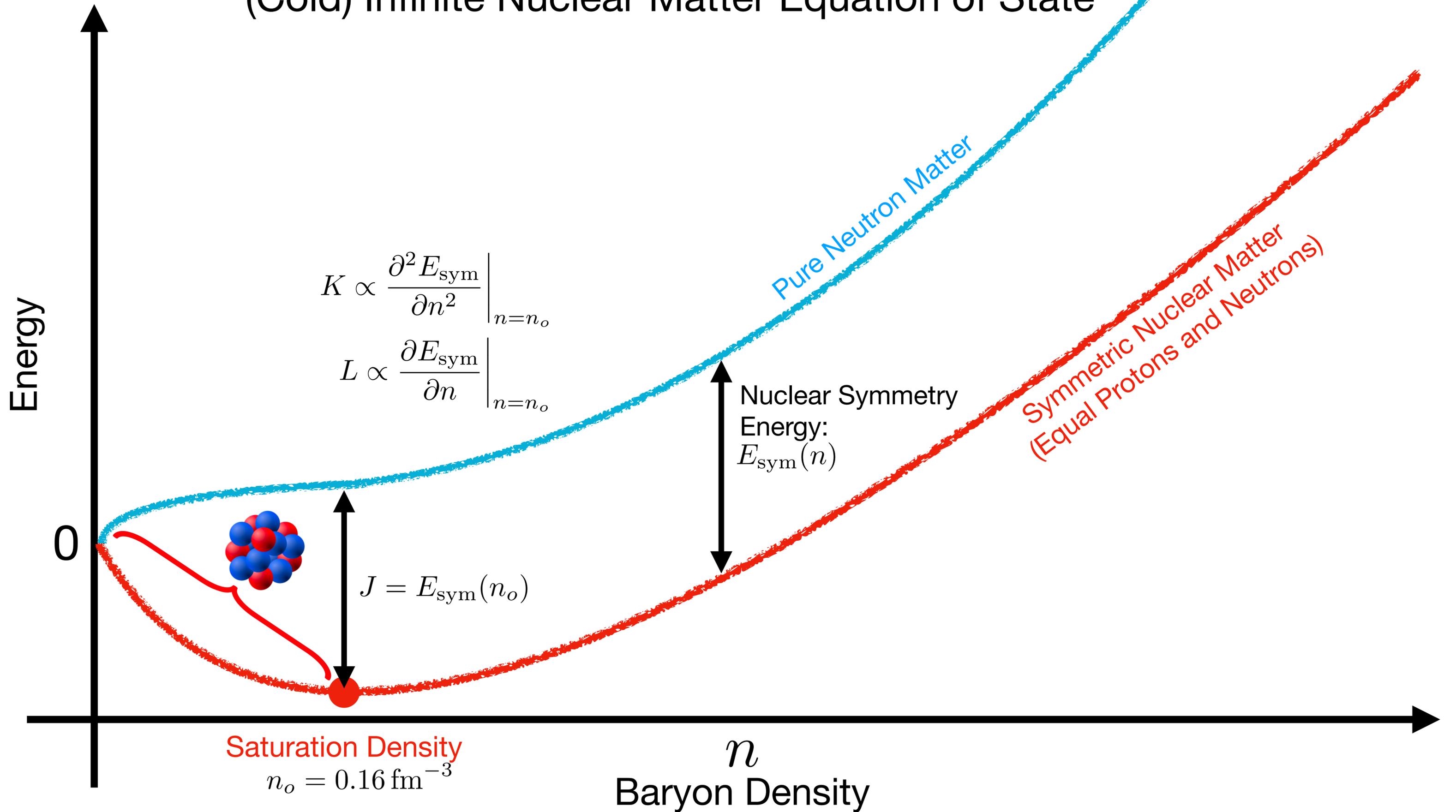
# Phase Diagram of Nuclear Matter

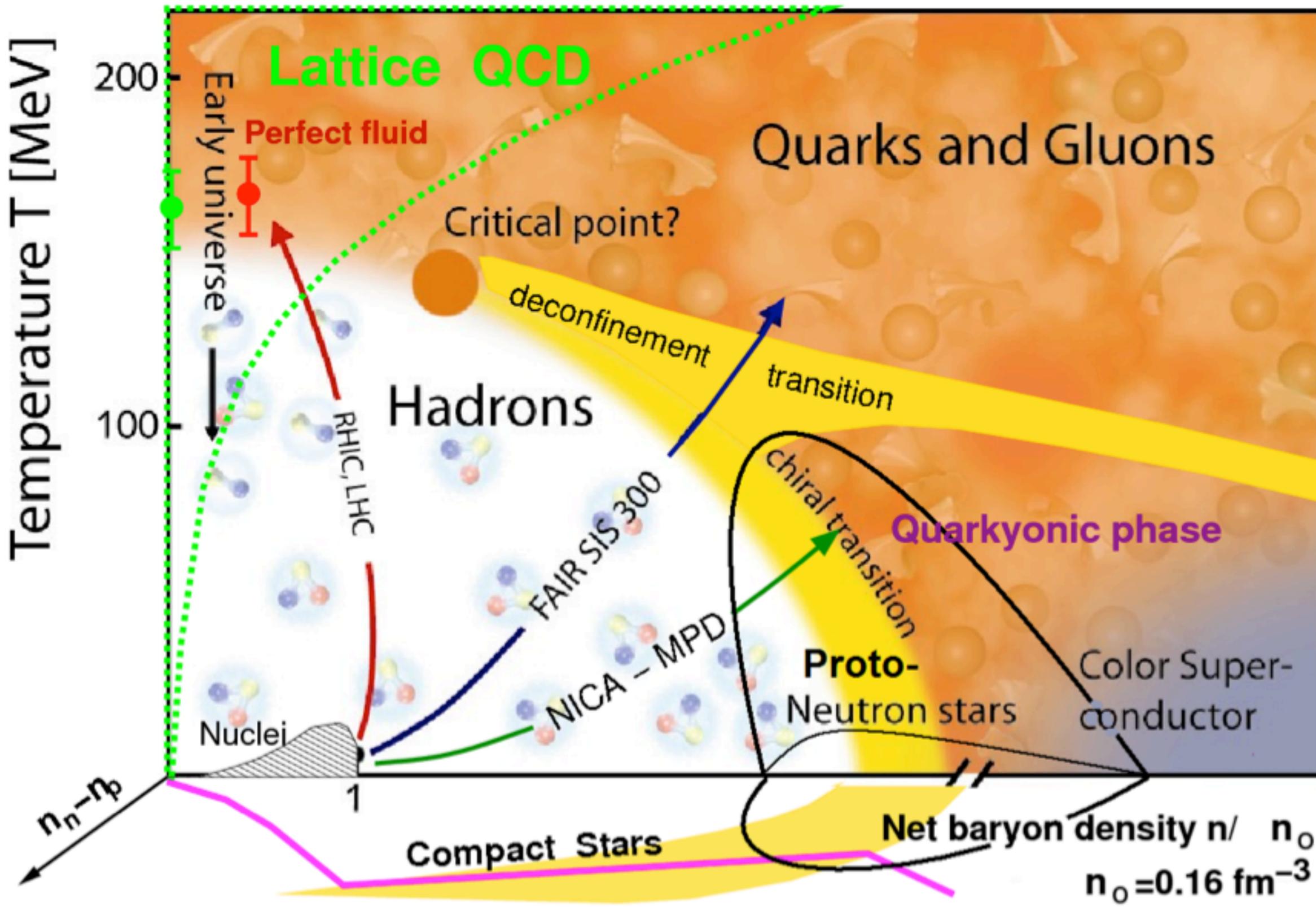


# Phase Diagram of Nuclear Matter



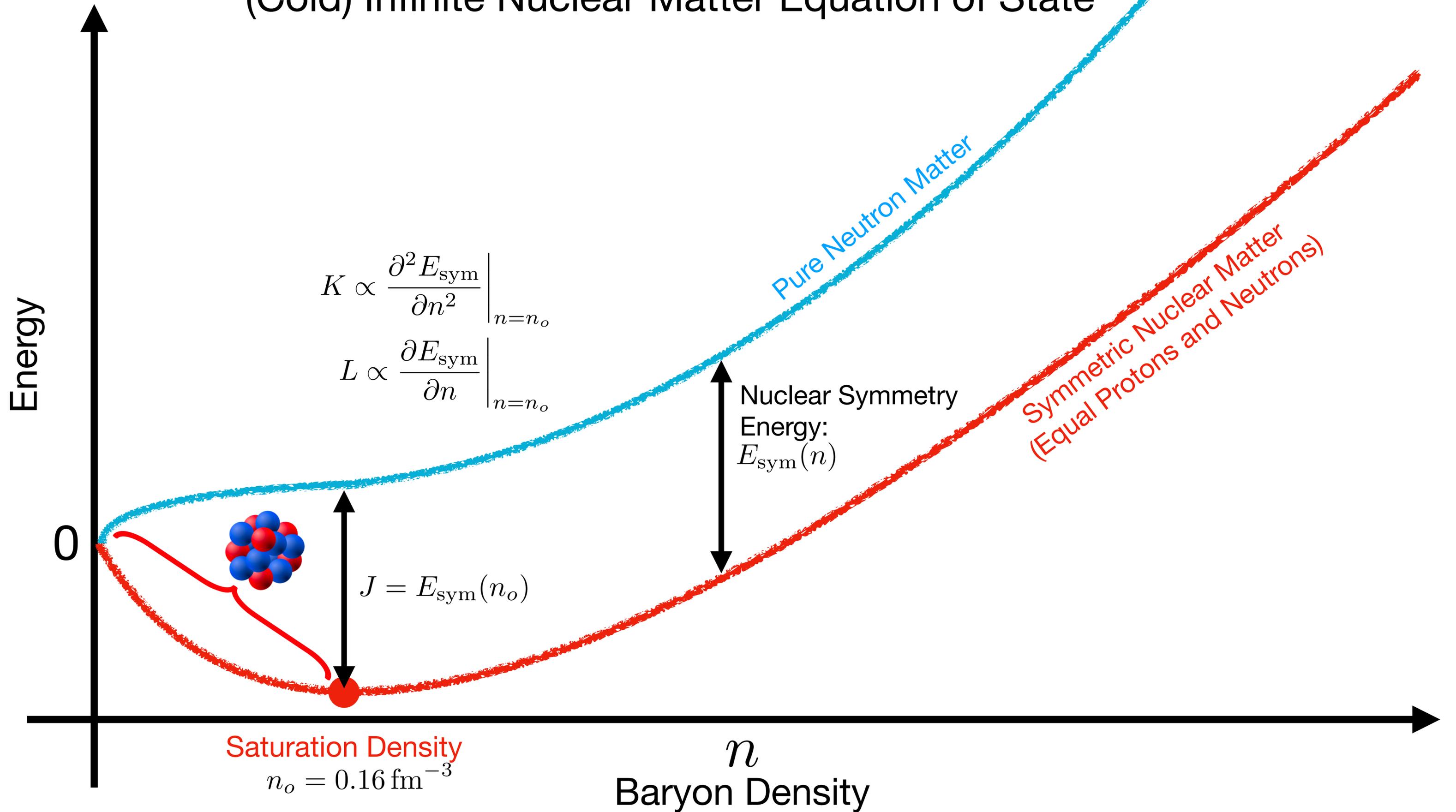
# (Cold) Infinite Nuclear Matter Equation of State



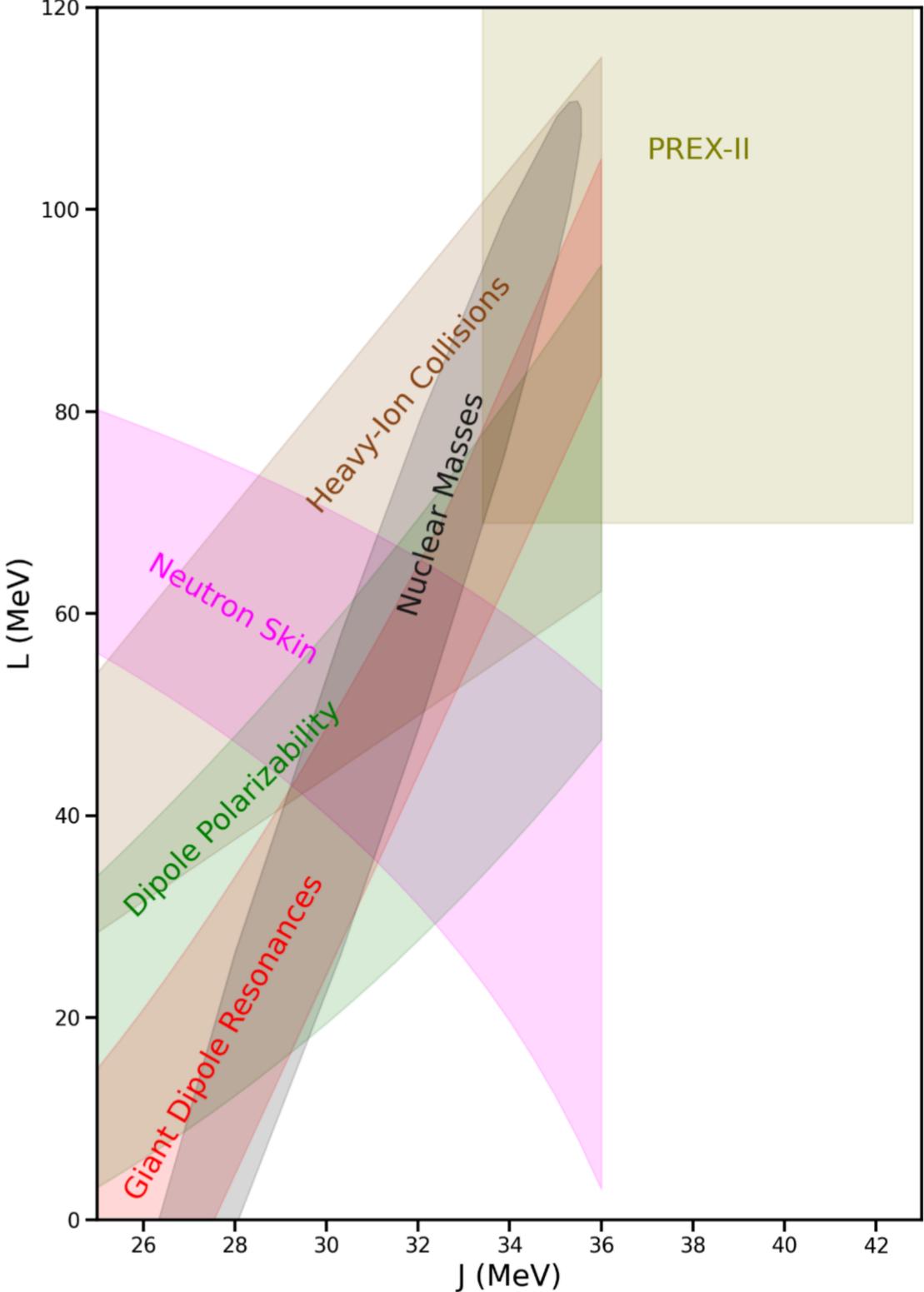


<https://web.infn.it/CSN4/IS/Linea3/STRENGTH/>

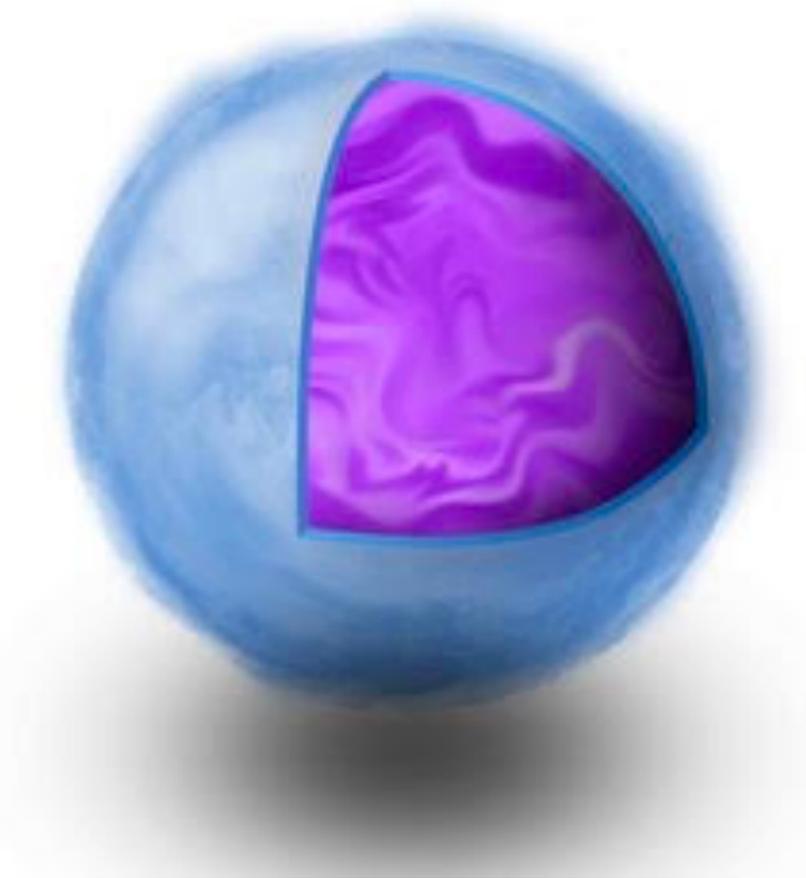
# (Cold) Infinite Nuclear Matter Equation of State



# Symmetry energy constraints from terrestrial experiments



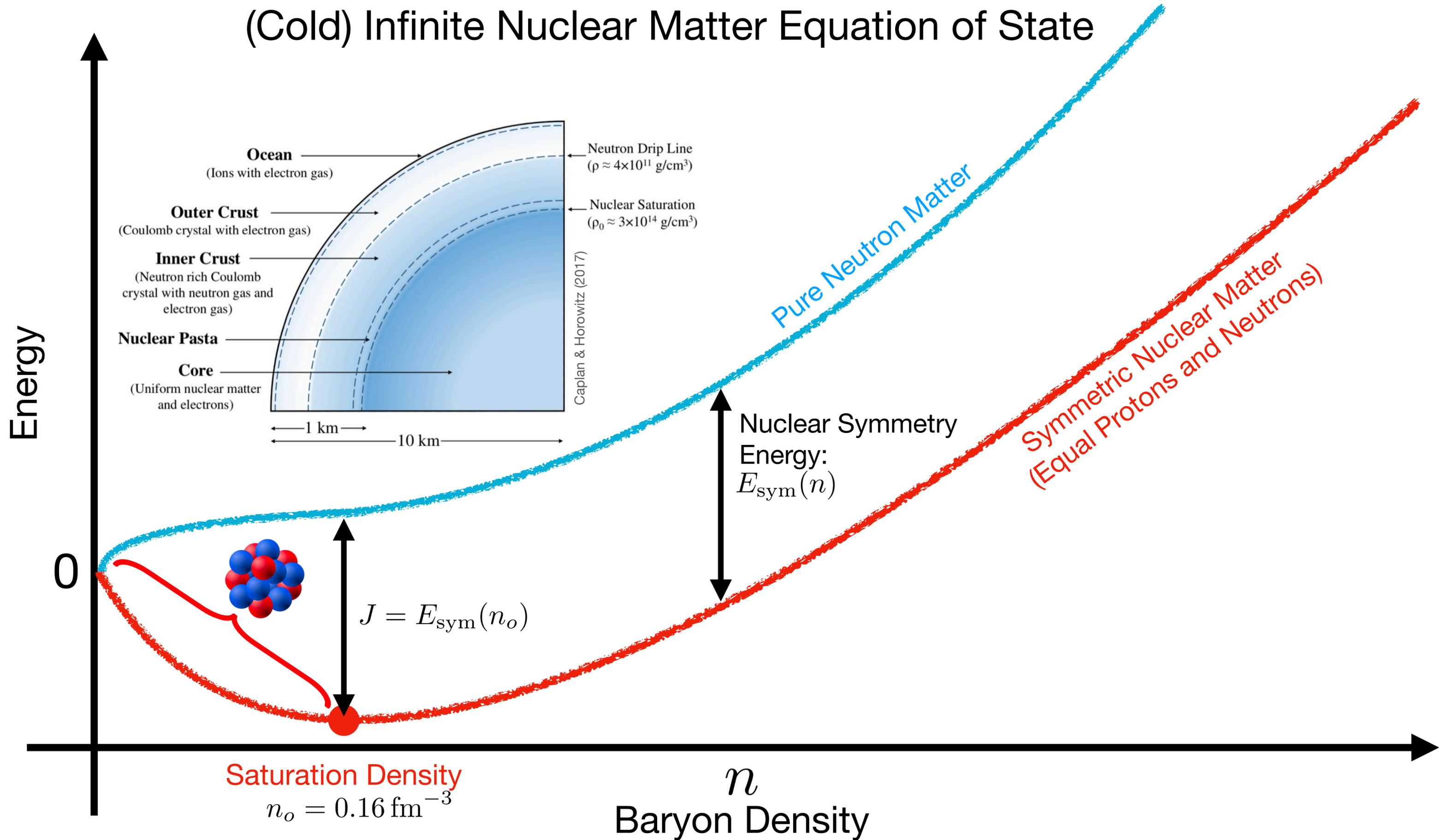
# Pb<sup>208</sup> Neutron “Skin” thickness

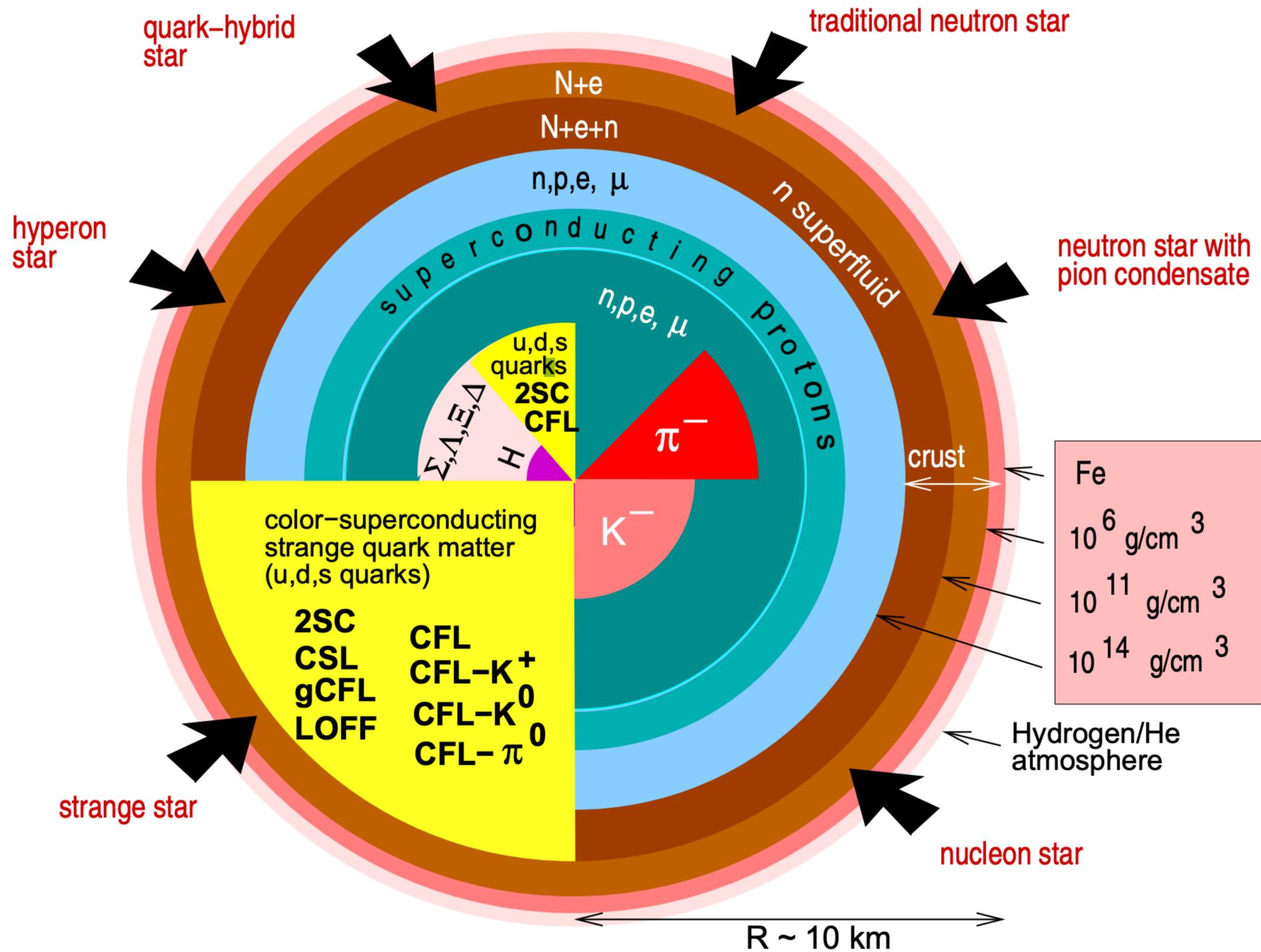


How can we measure Symmetry Energy with astrophysics?

Which regions of a neutron star tell us about which physics?

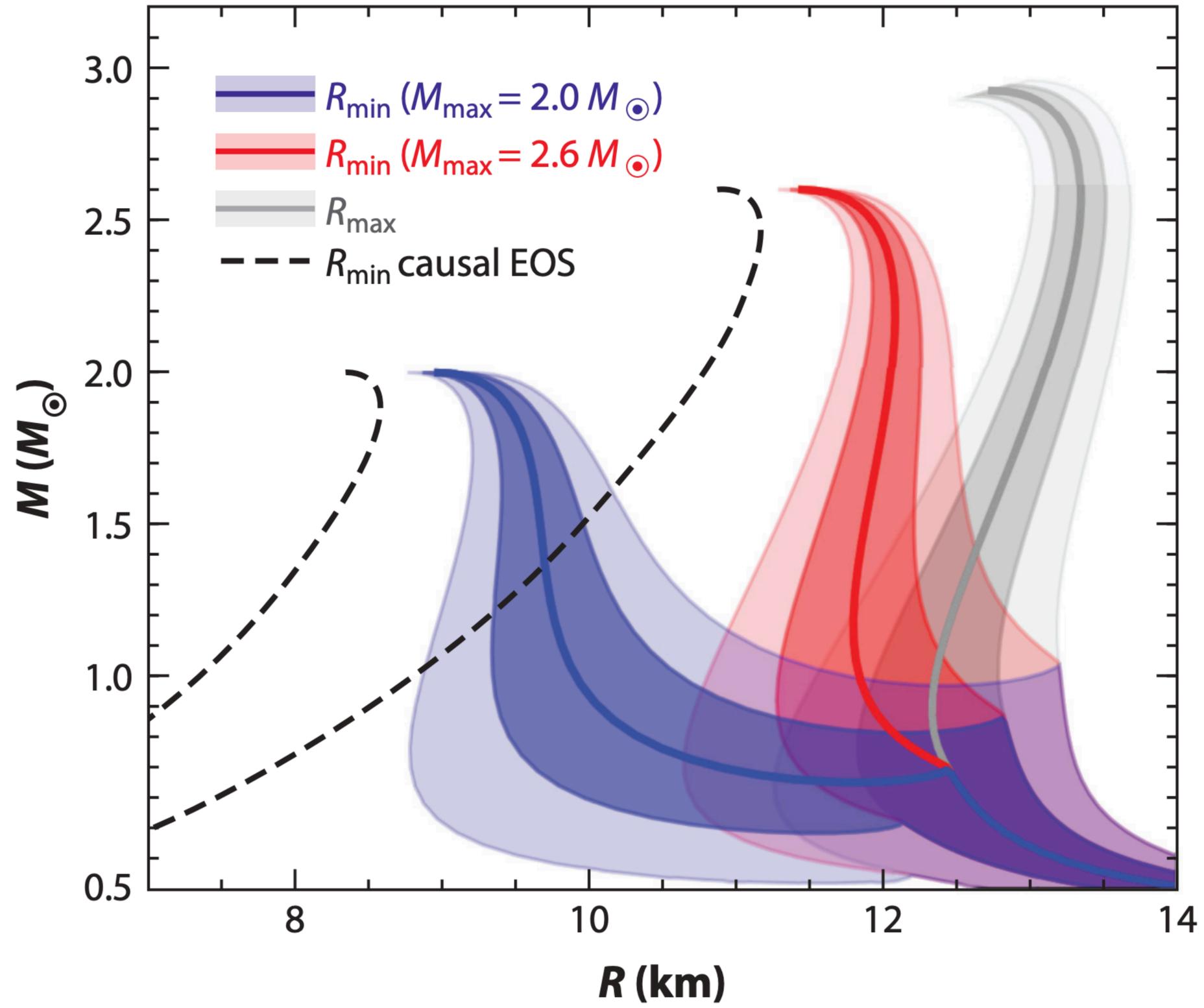
# (Cold) Infinite Nuclear Matter Equation of State

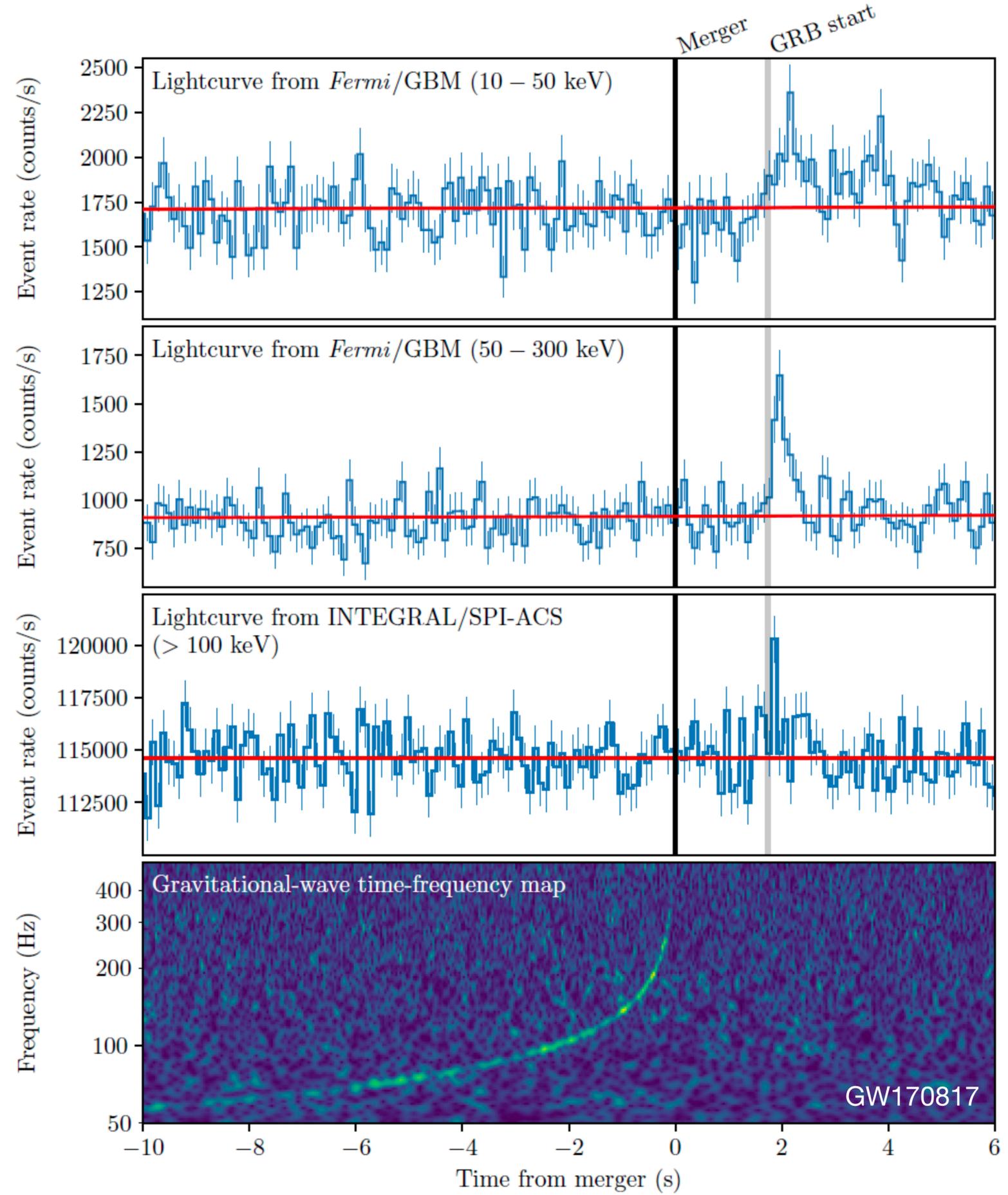


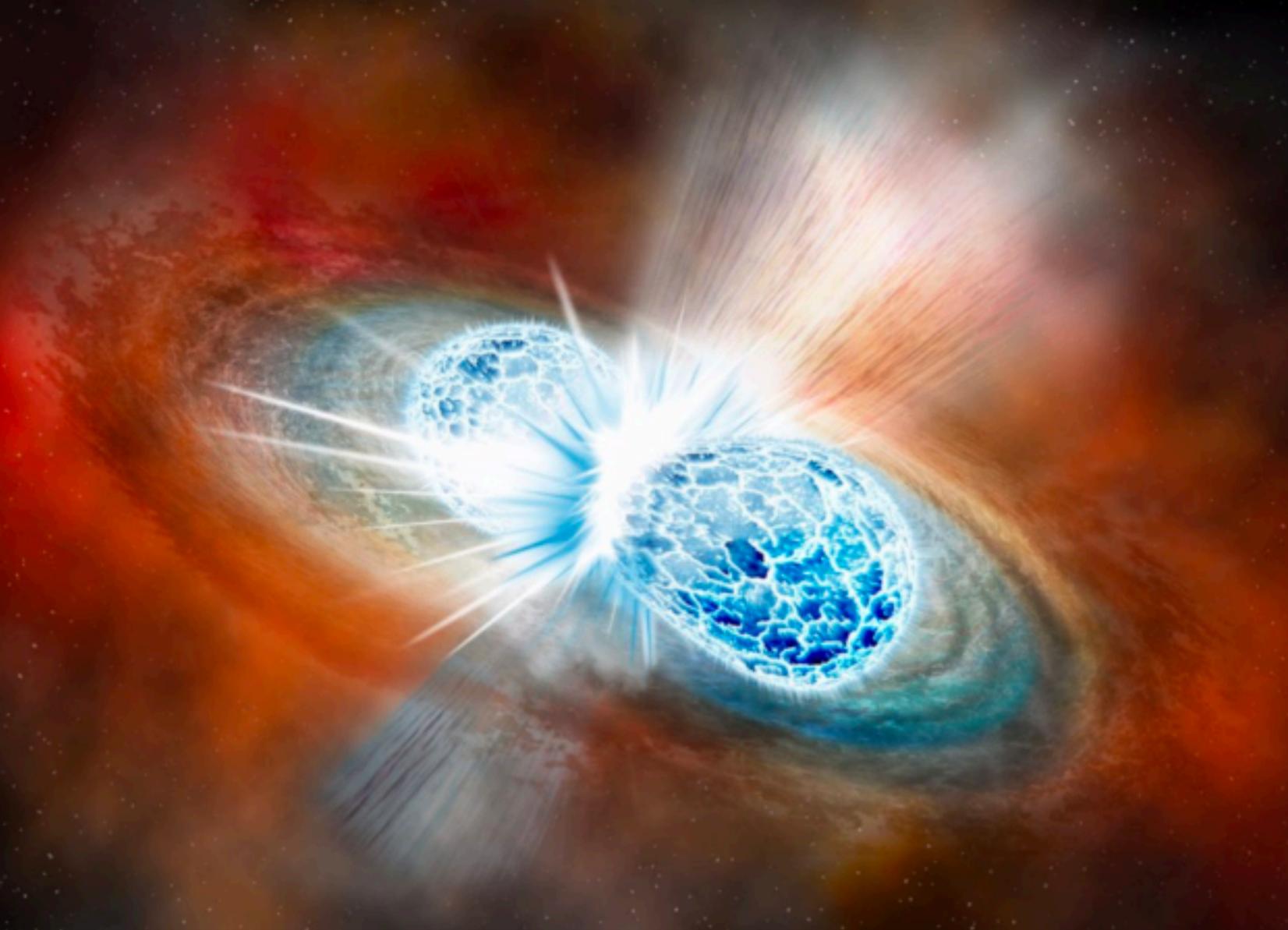




M-R mostly a function of core properties (e.g. chiral EFT constraints)

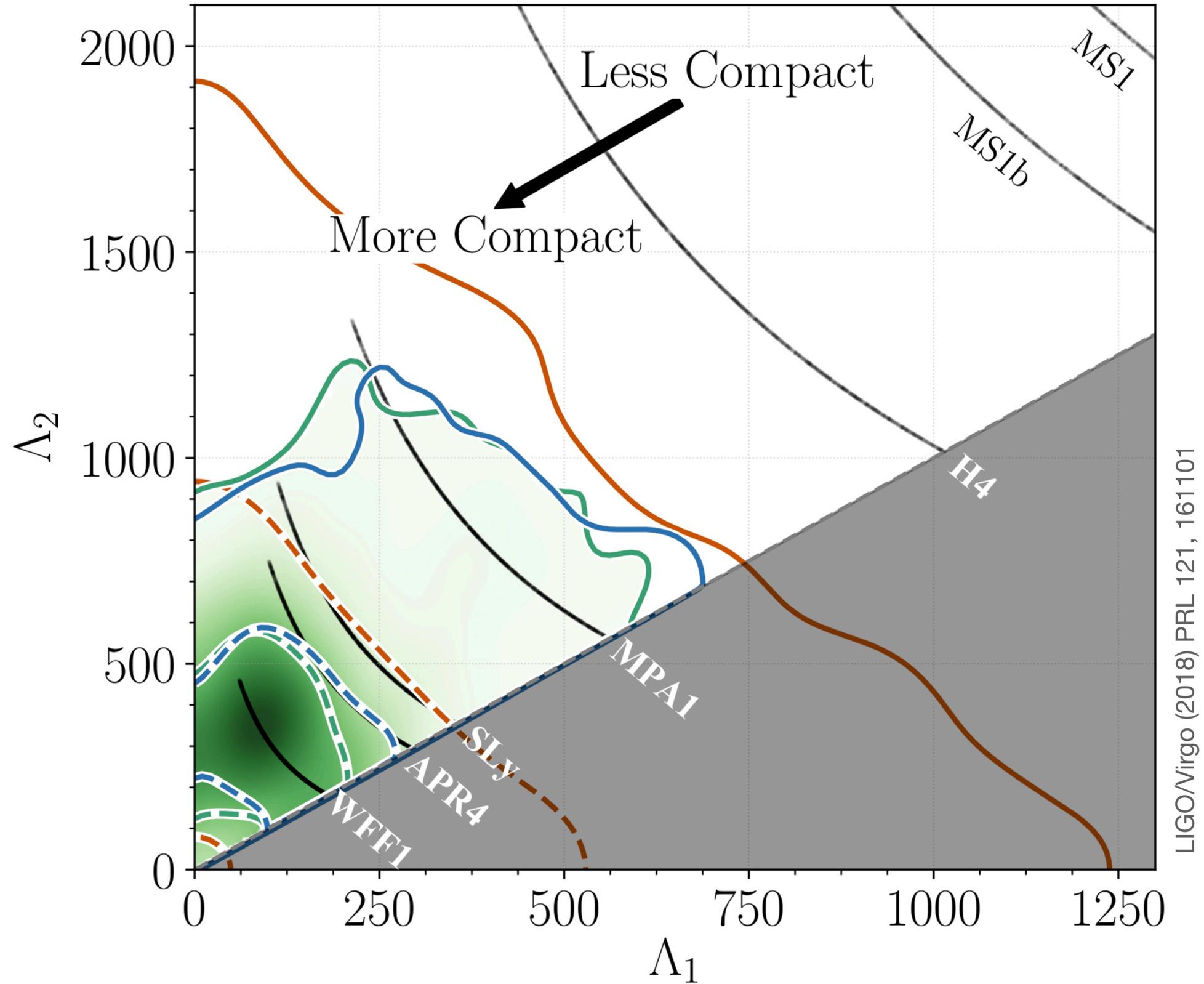


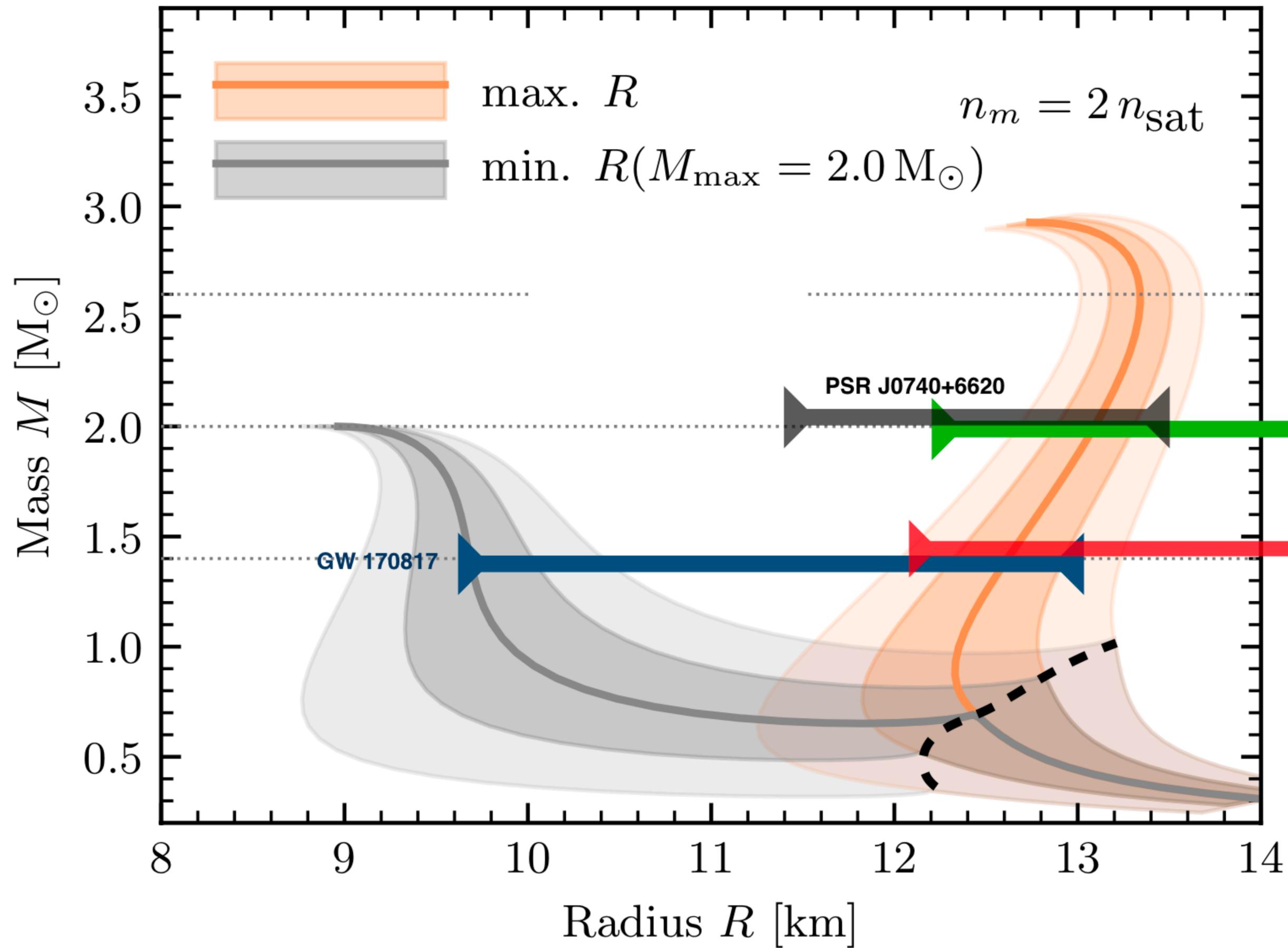




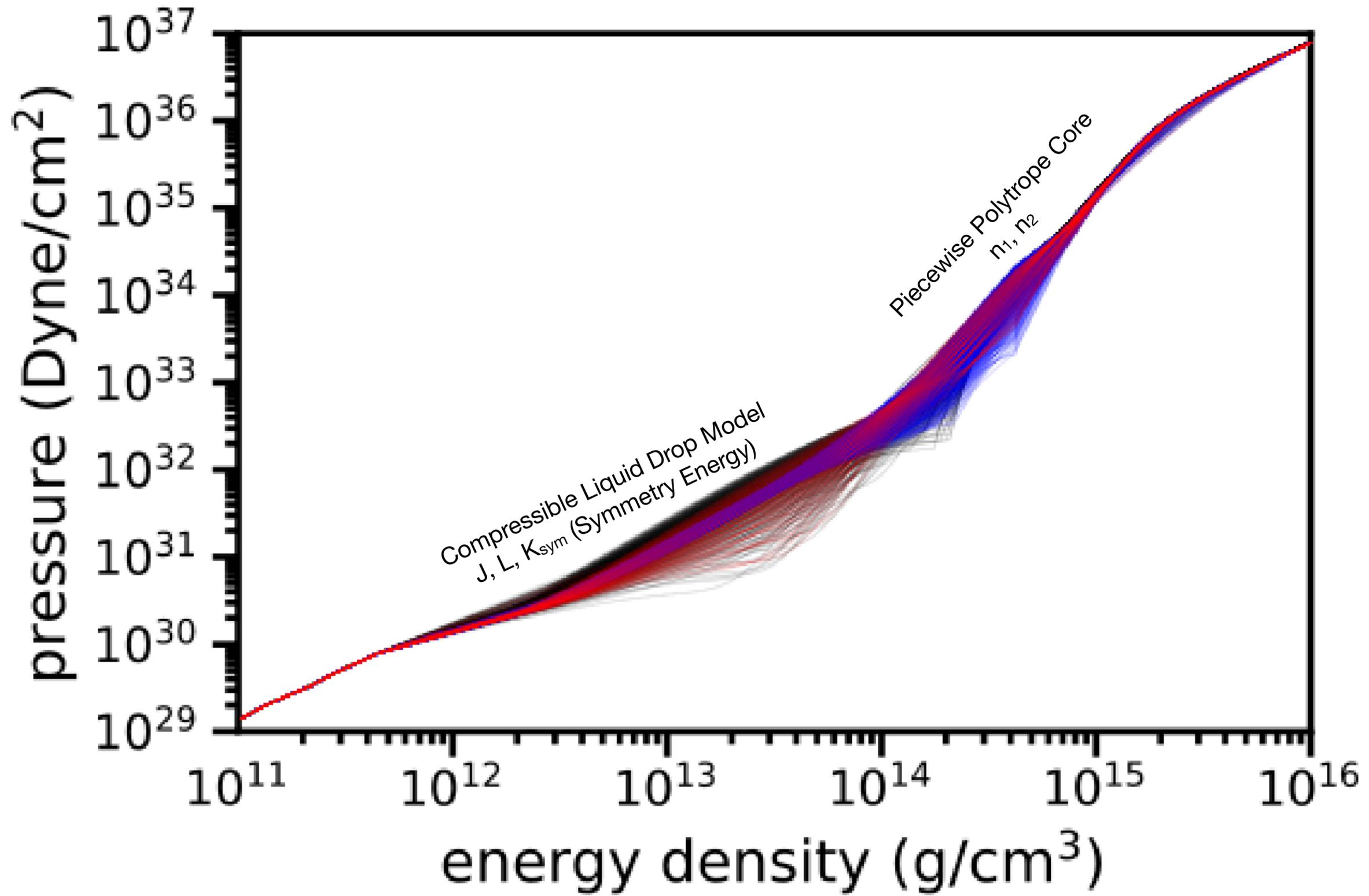
**Kilonovae and Short Gamma Ray Bursts tell us a lot about the messy post-merger physics!  
But not too much about the neutron star progenitors themselves...**

# Tidal deformability mostly a function of core properties

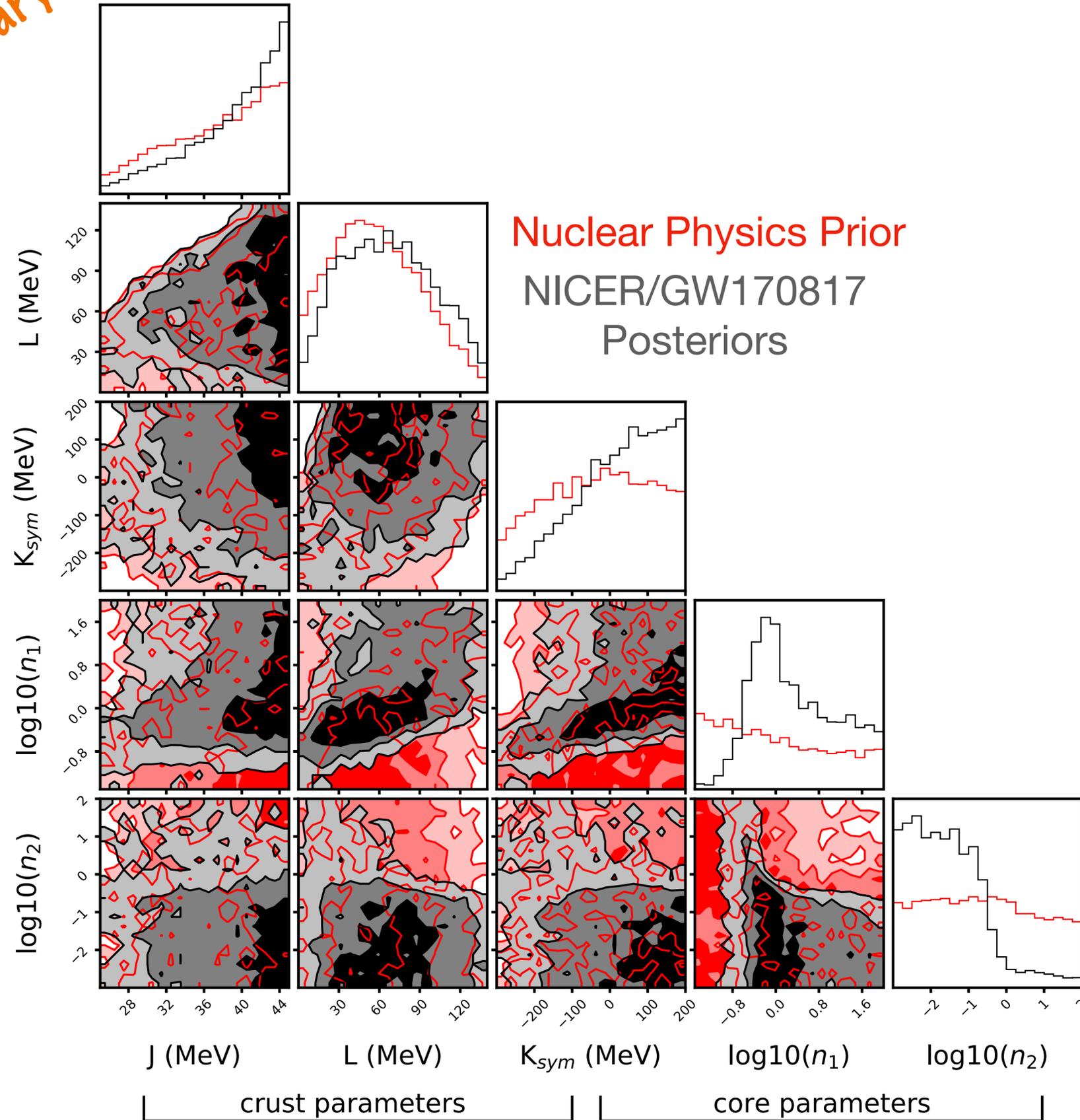




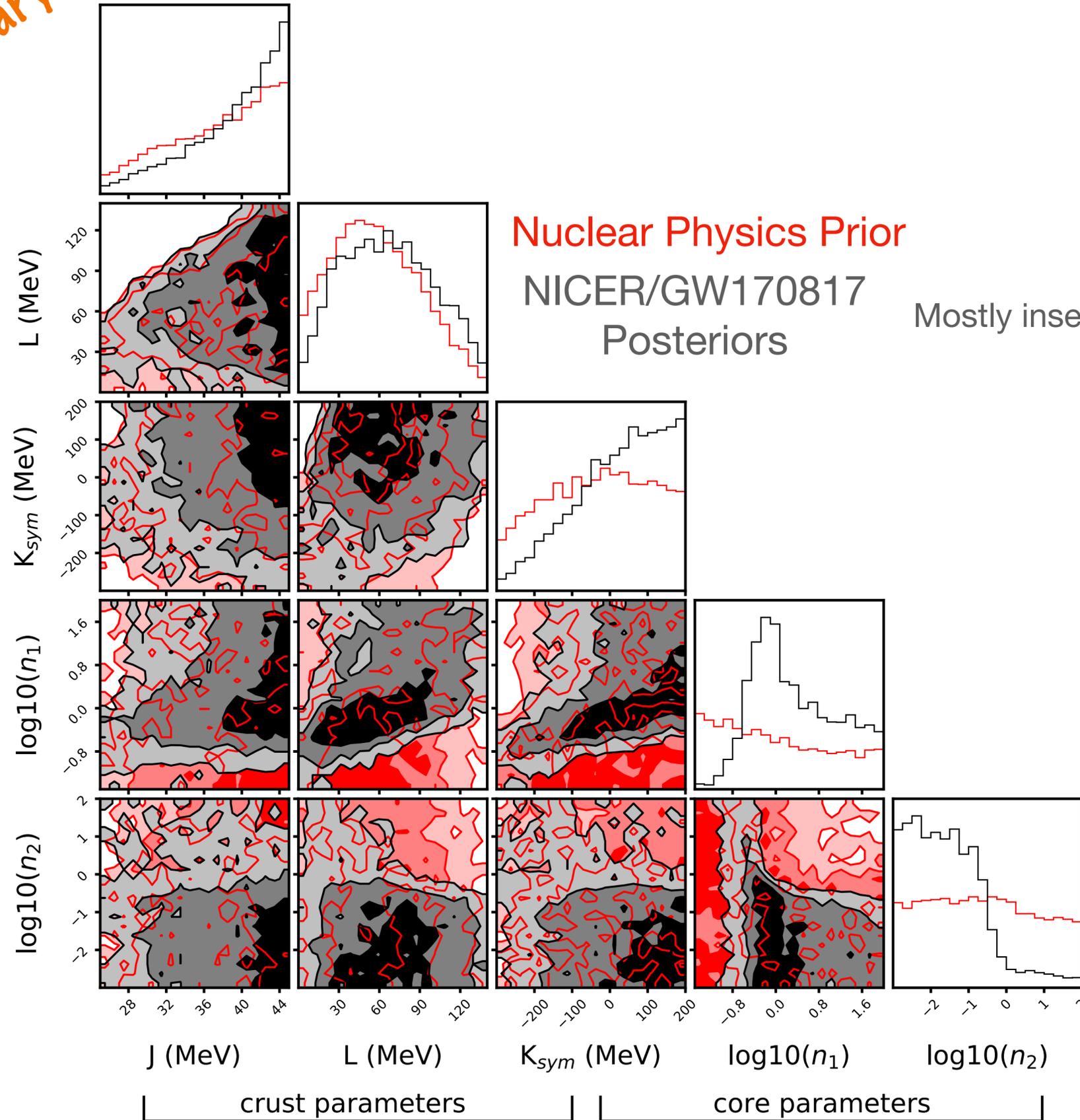
# Parameterised Crust and Core



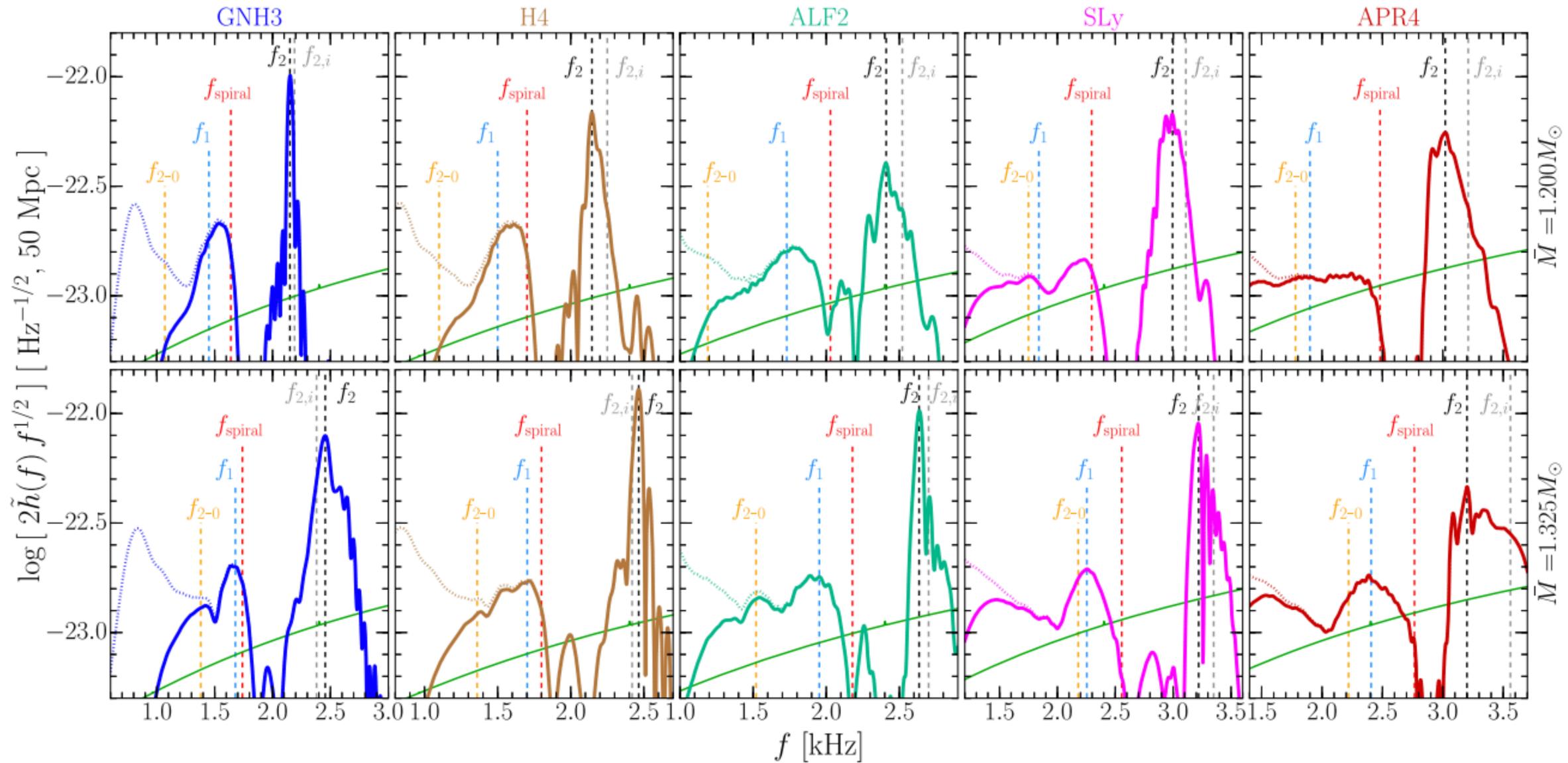
Preliminary



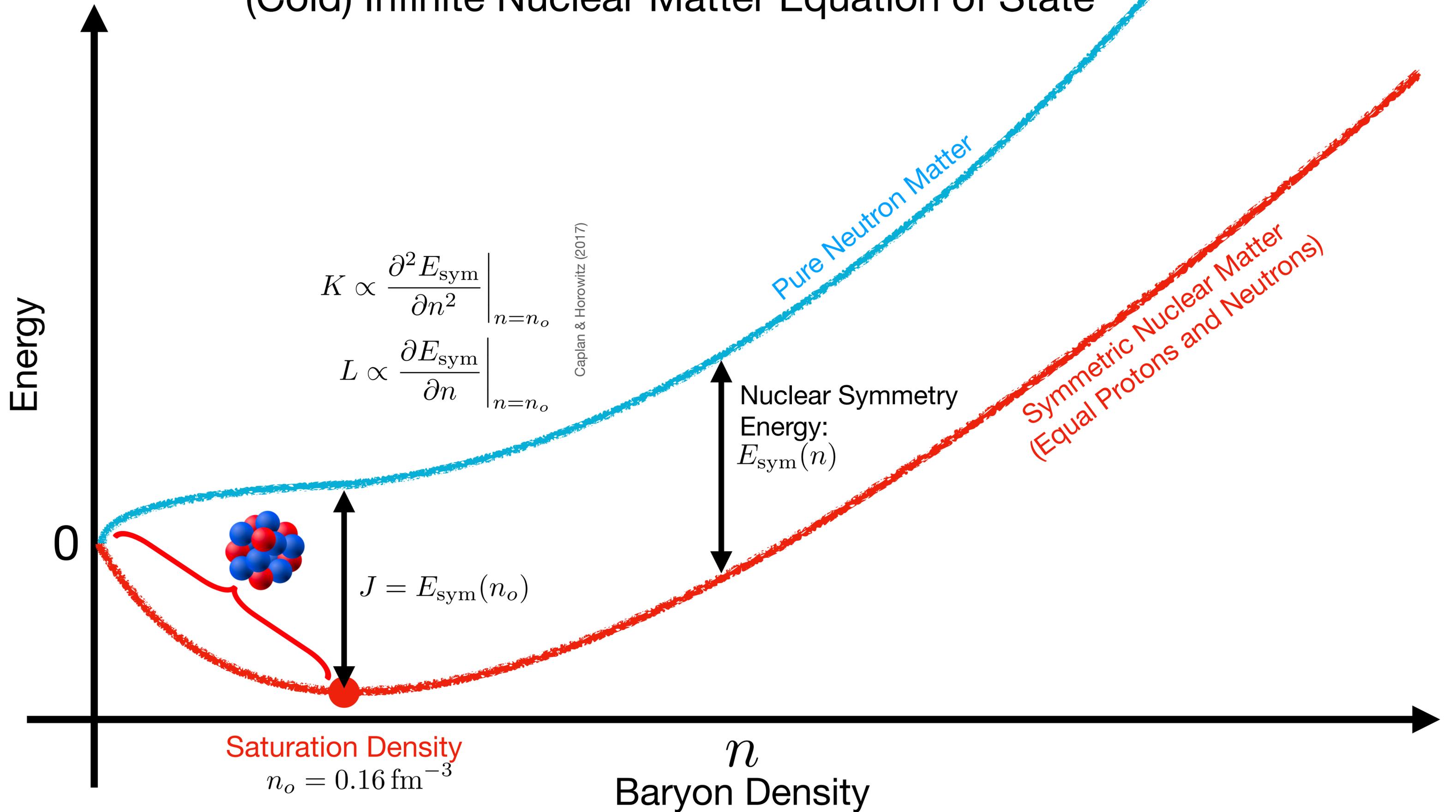
Preliminary



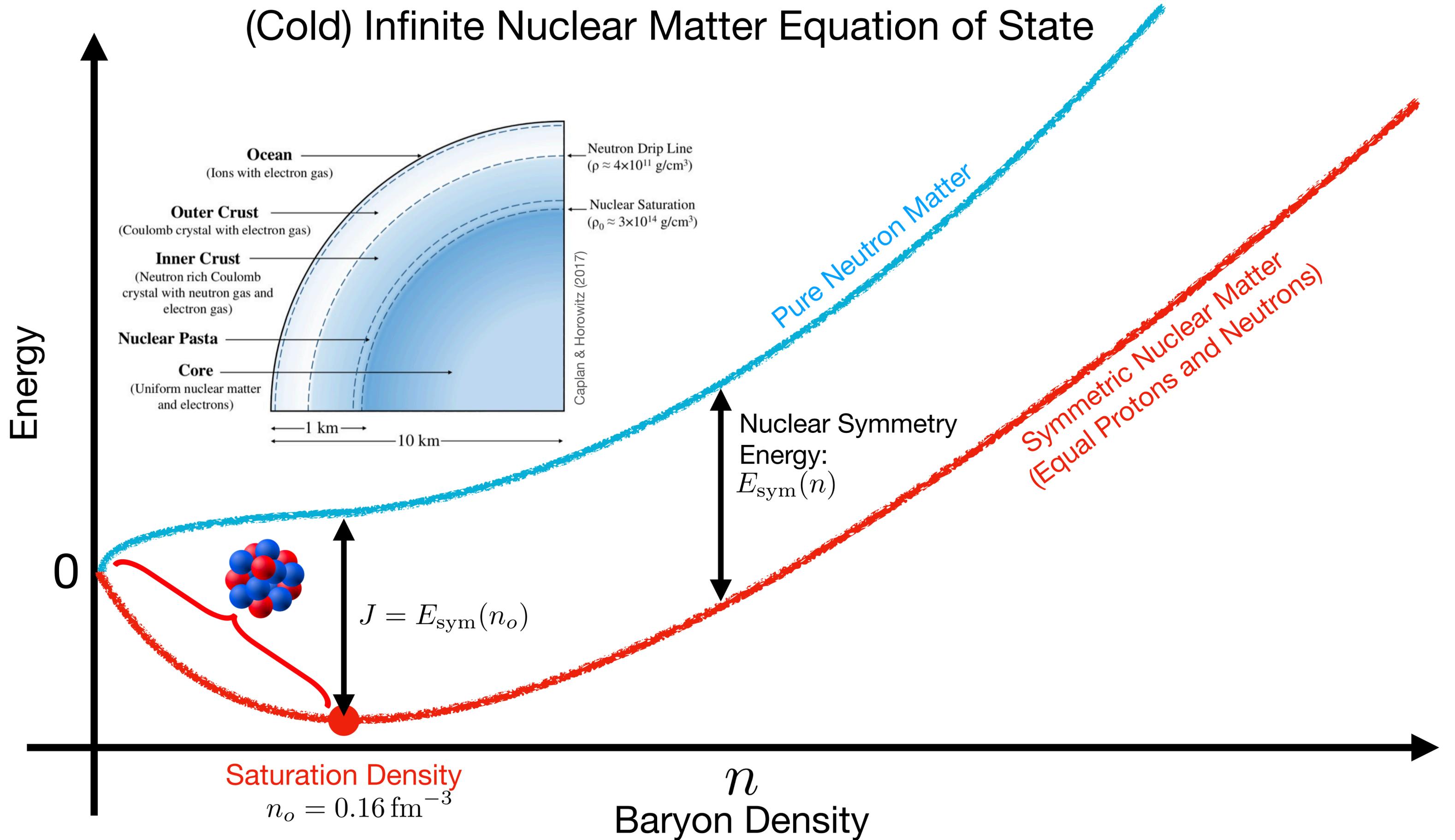
# GW “Spectroscopy” of a HMNS Remnant



# (Cold) Infinite Nuclear Matter Equation of State



# (Cold) Infinite Nuclear Matter Equation of State

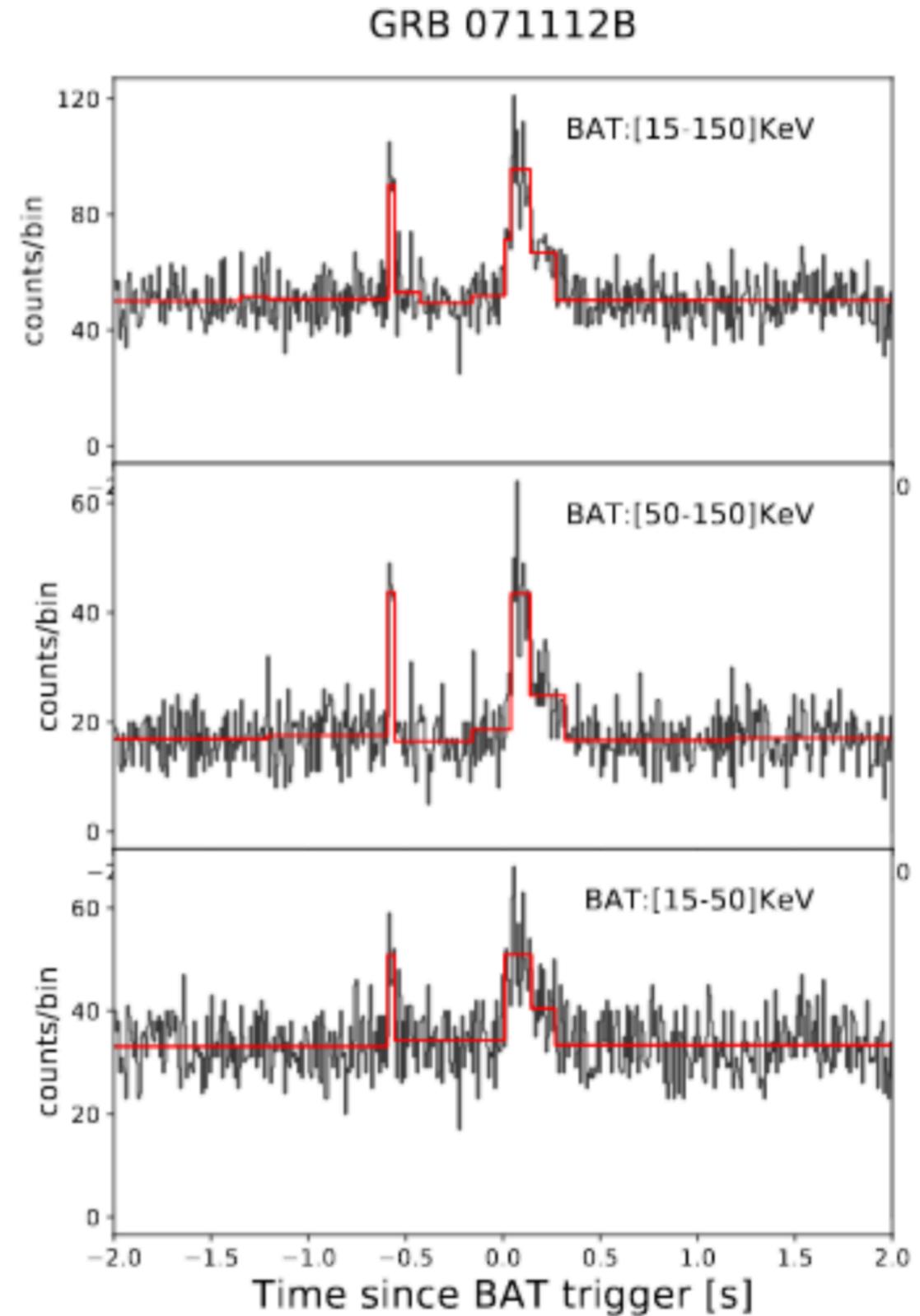
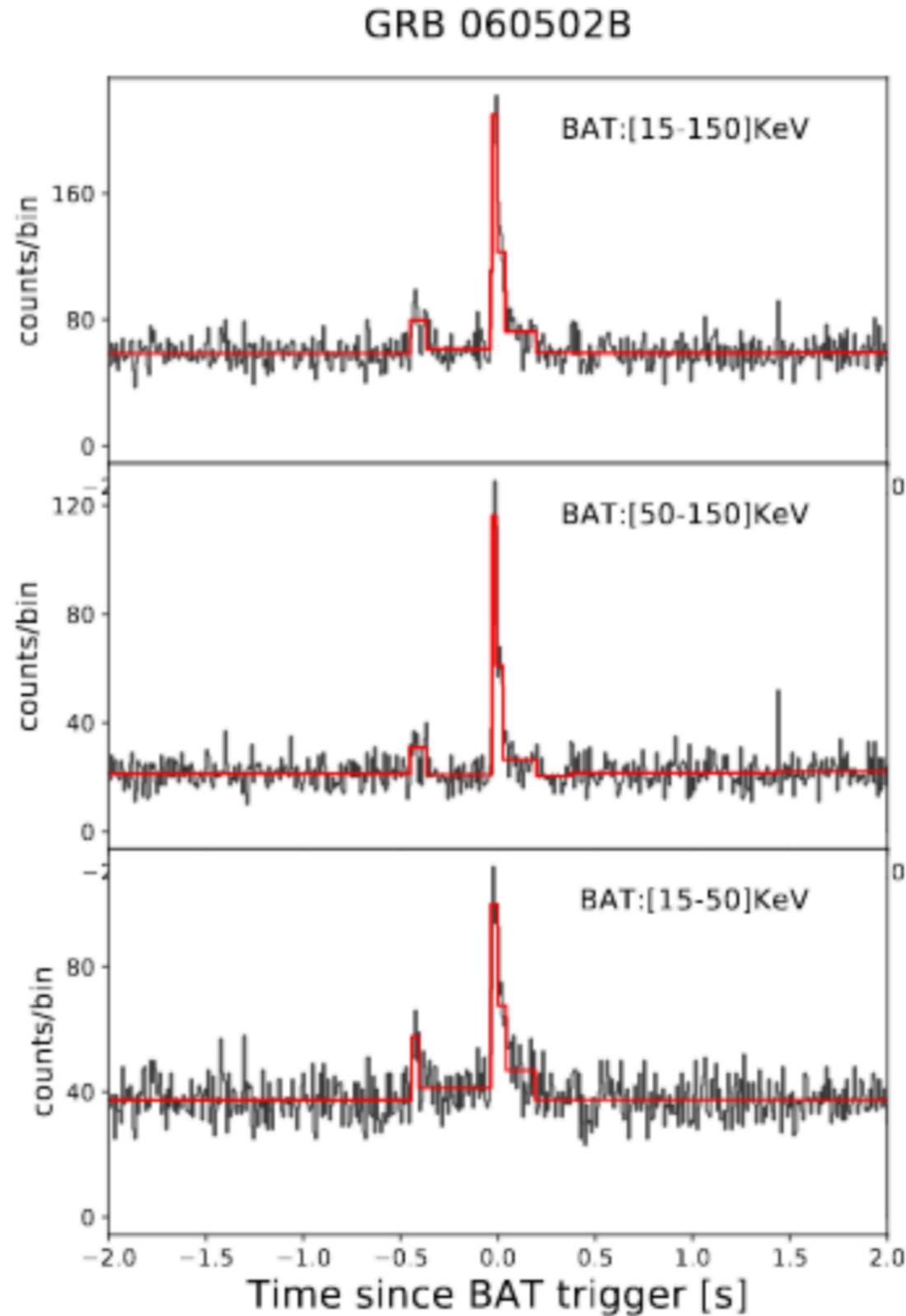


AN OBSERVABLE THAT CAN BE USED TO  
PROBE STRUCTURE OF THE INNER  
CRUST AND THEREFORE NUCLEAR  
SYMMETRY ENERGY

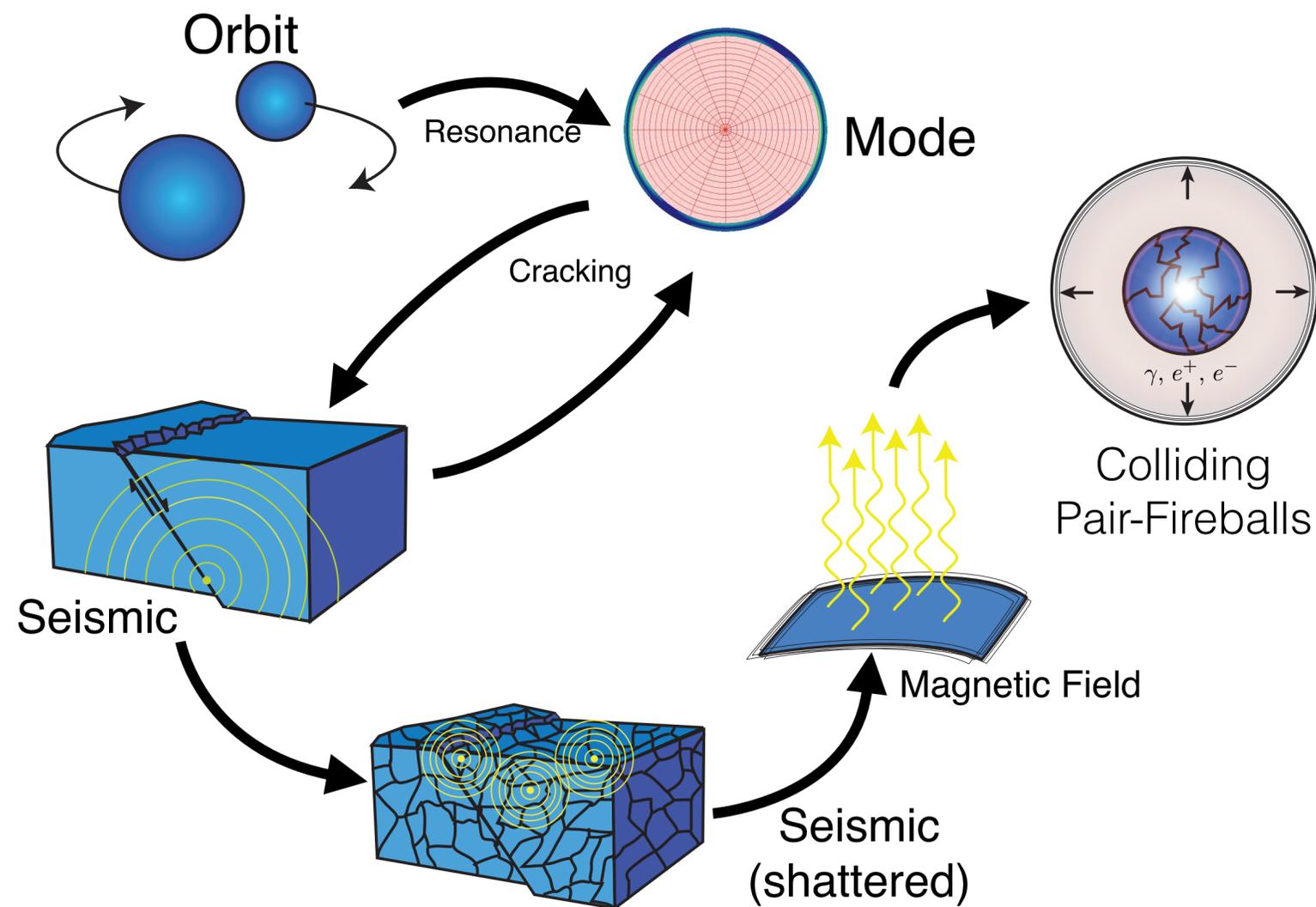


What are Resonant Shattering Flares (RSFs)?

# Some SGRBs have precursors...



# Resonant Shattering Flares

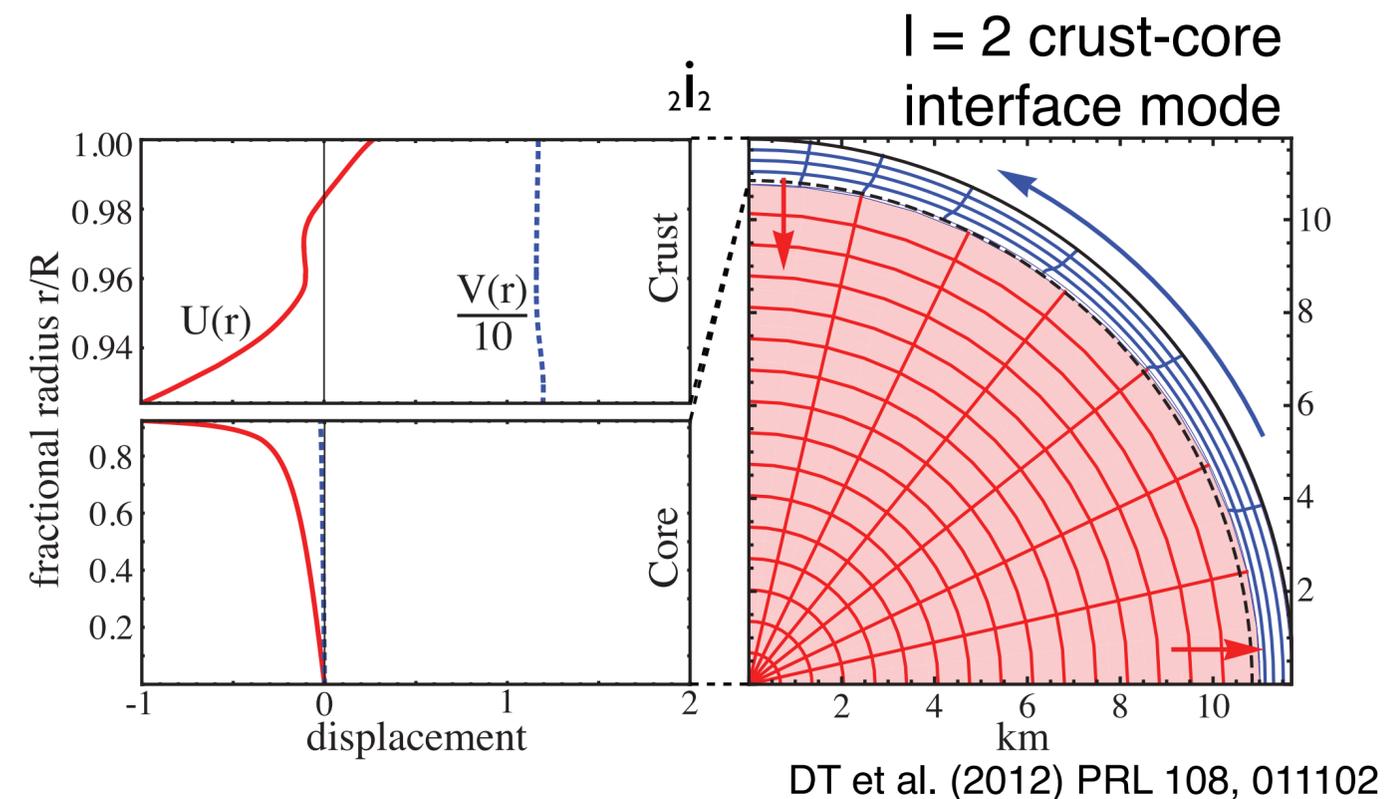
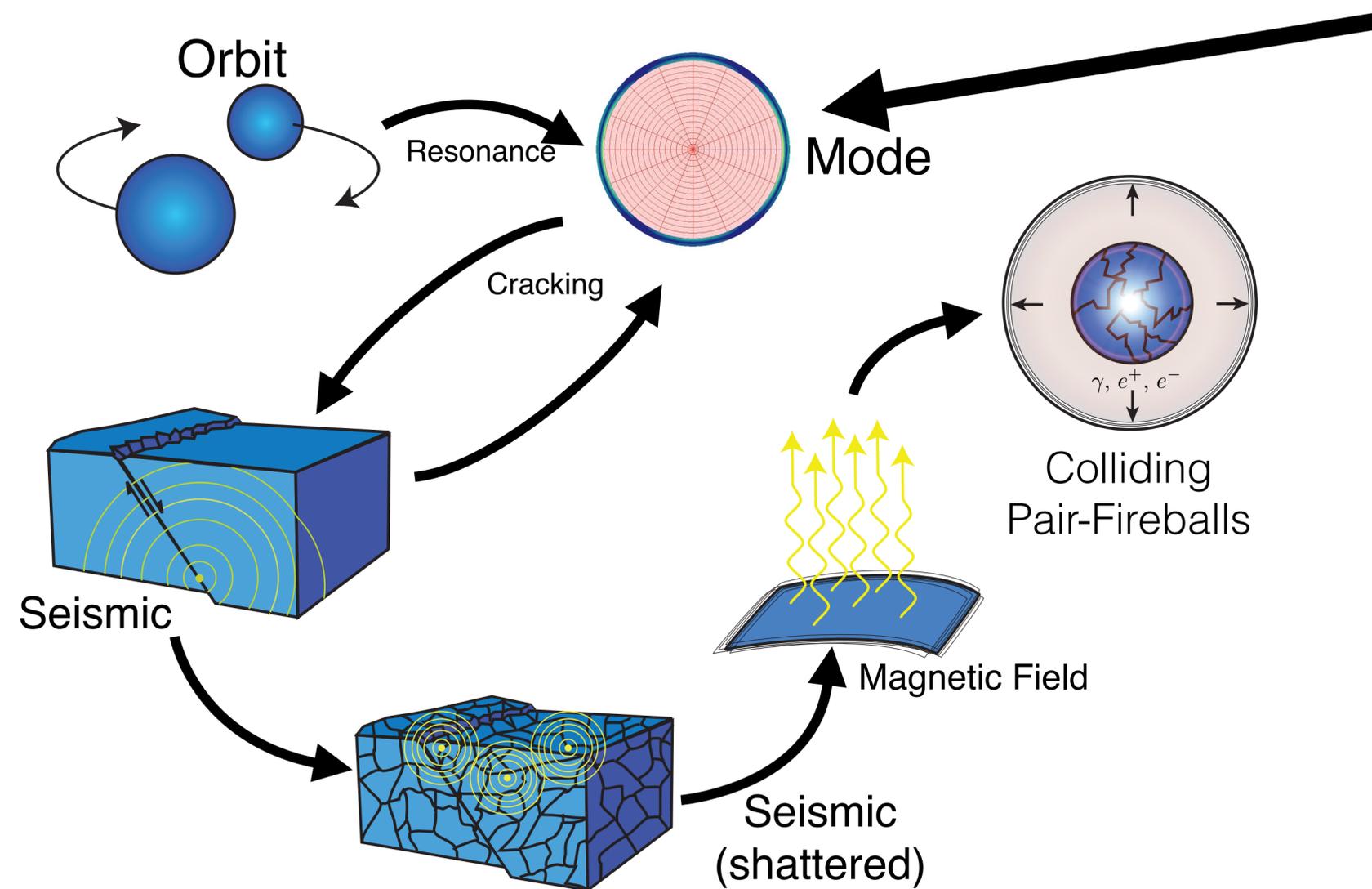


DT, et al. (2012) PRL 108, 011102

DT (2013) ApJ 777, 103

Neill, DT, Van Eerten, Ryan, & Newton (2022) MNRAS in press

# Resonant Shattering Flares

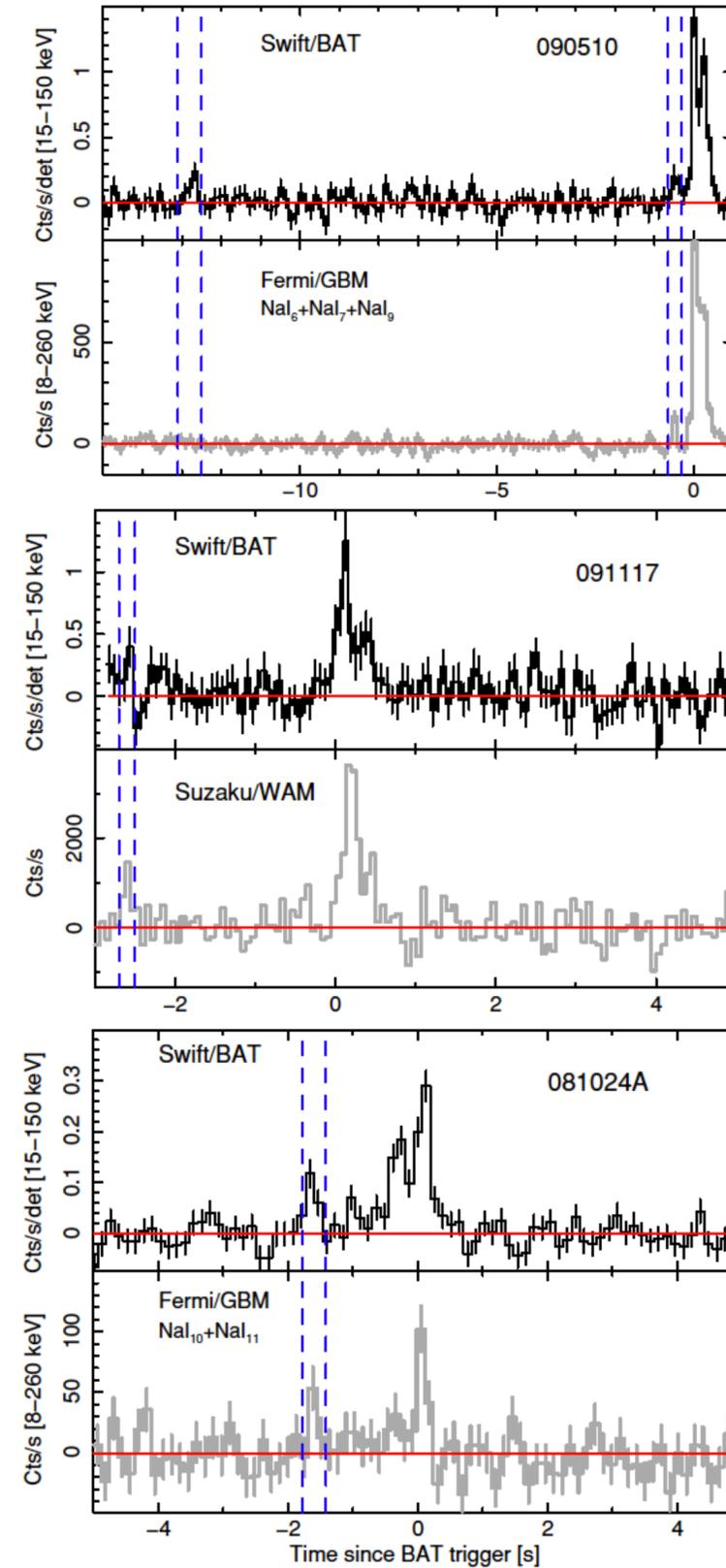
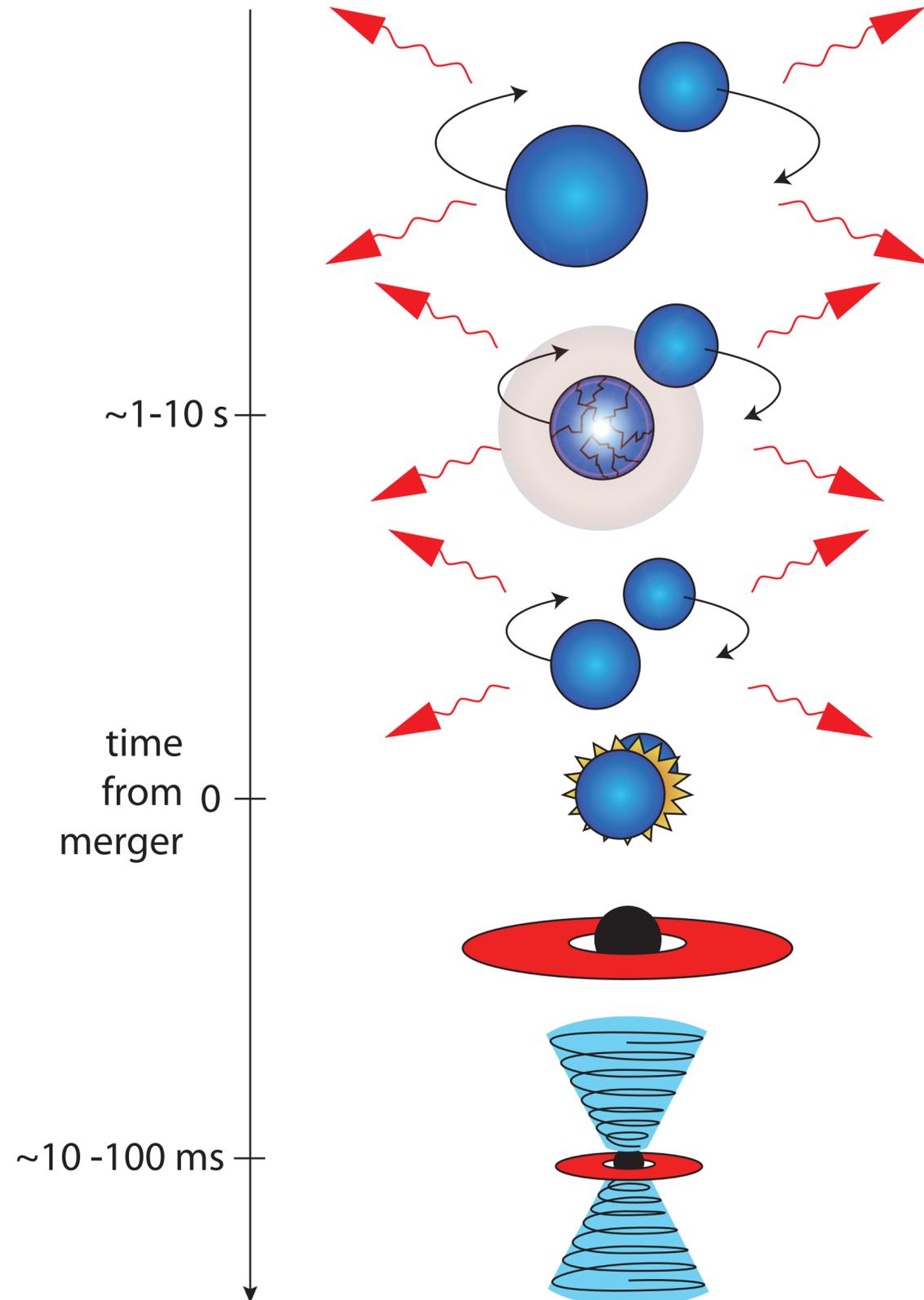


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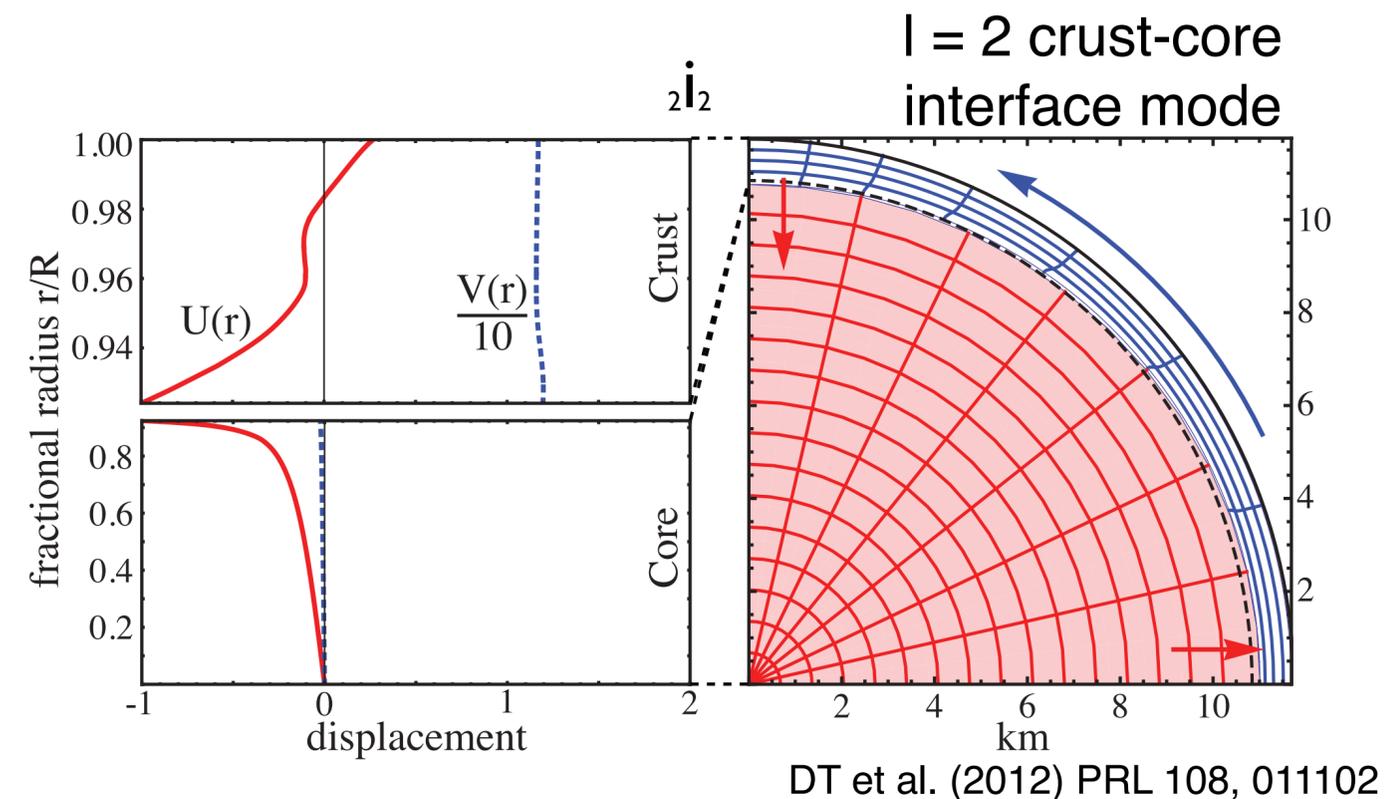
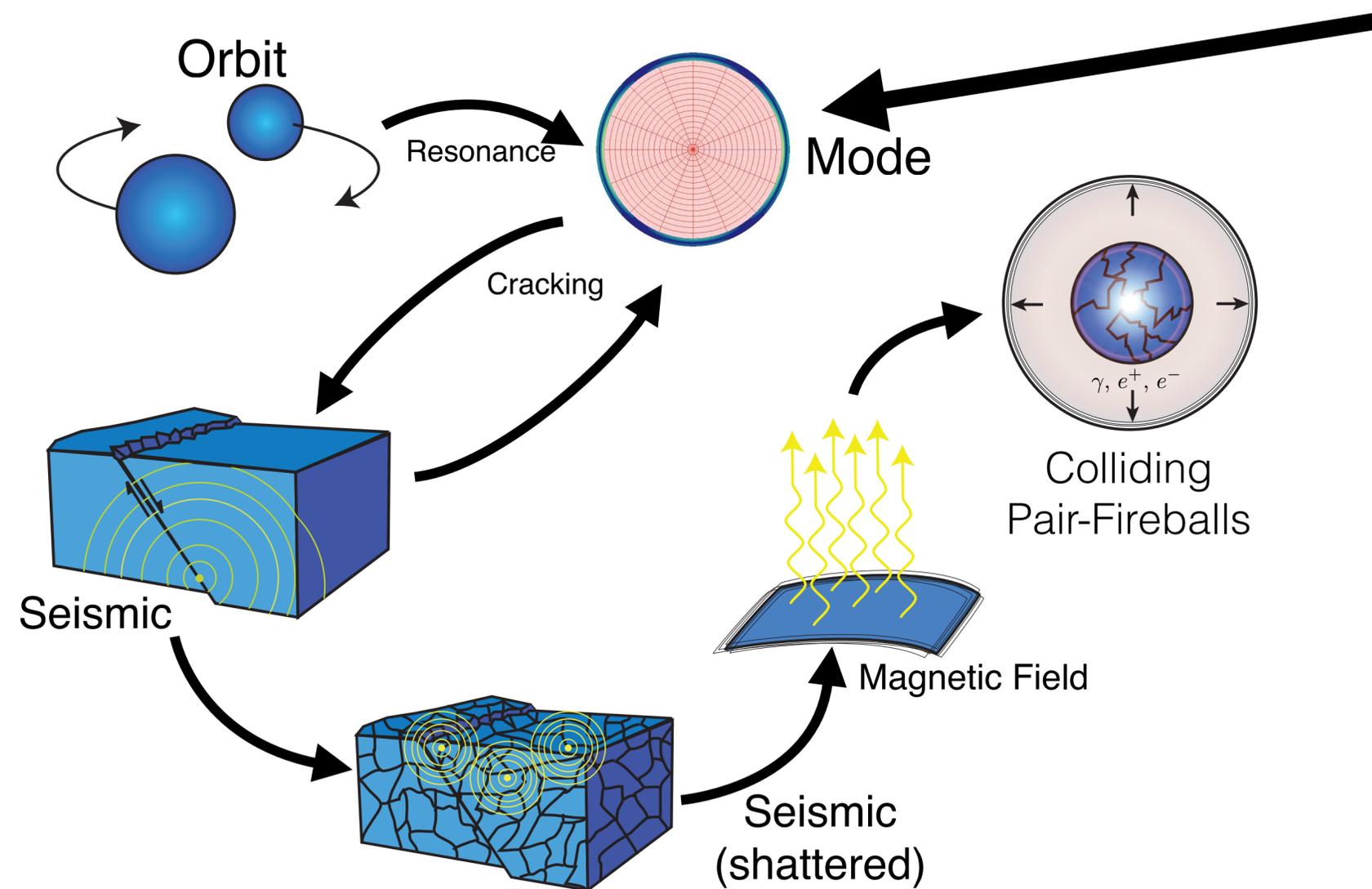
# Some SGRBs have precursors...



Troja et al. ApJ, 723, 1711 (2010)

How can we use RSFs to constrain nuclear physics?  
How do RSFs compare to collider experiments?

# Resonant Shattering Flares

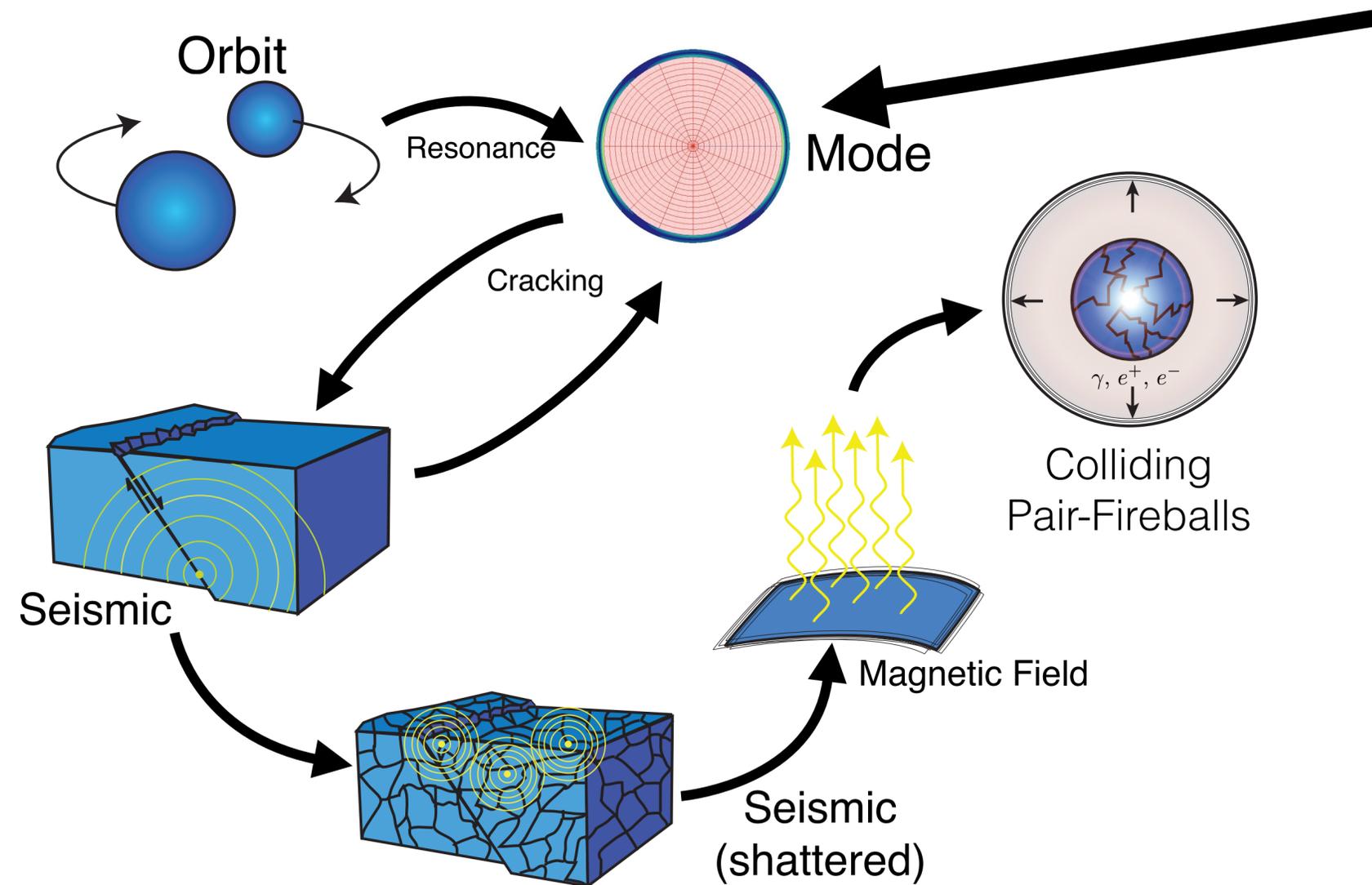


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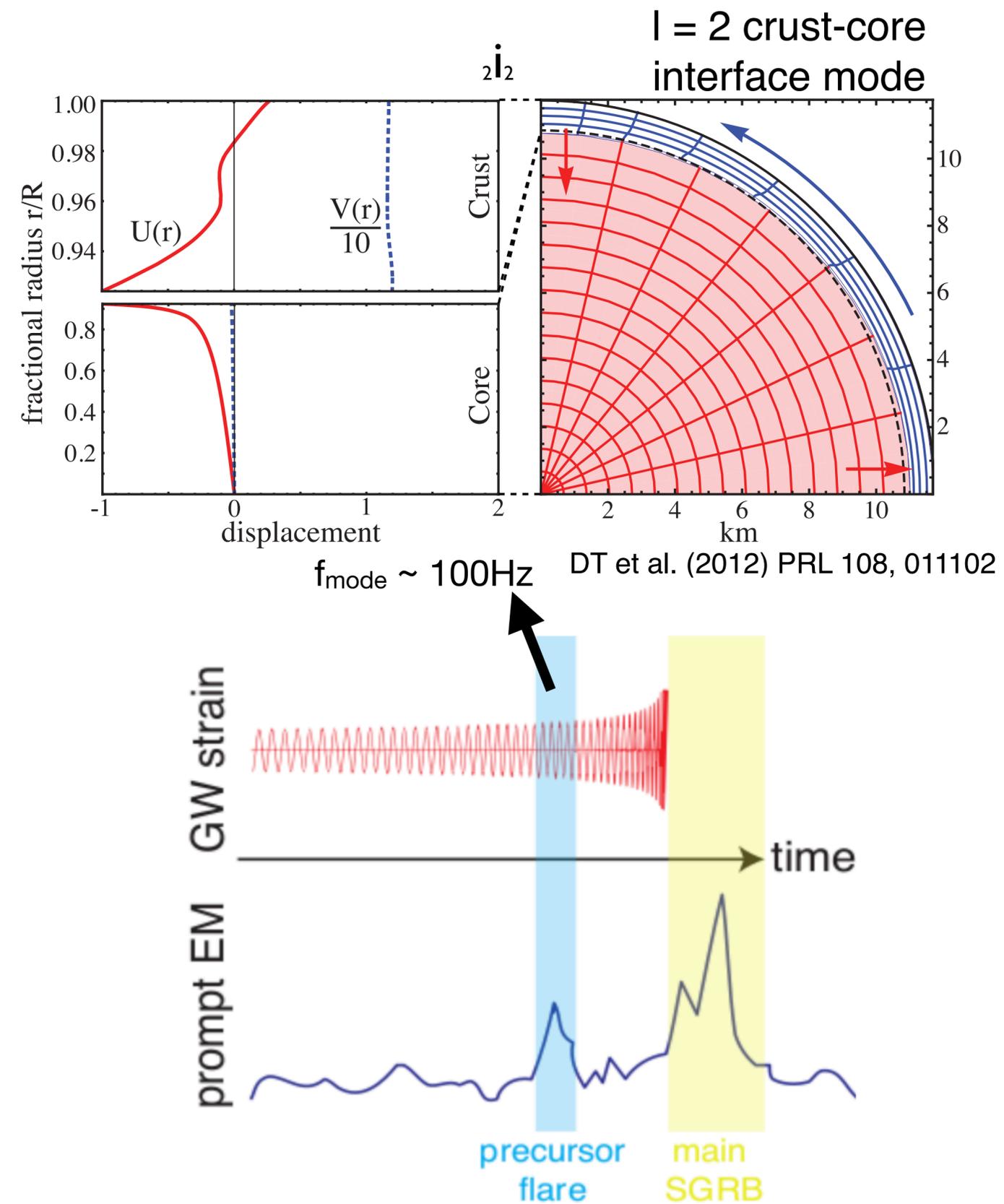
# Resonant Shattering Flares

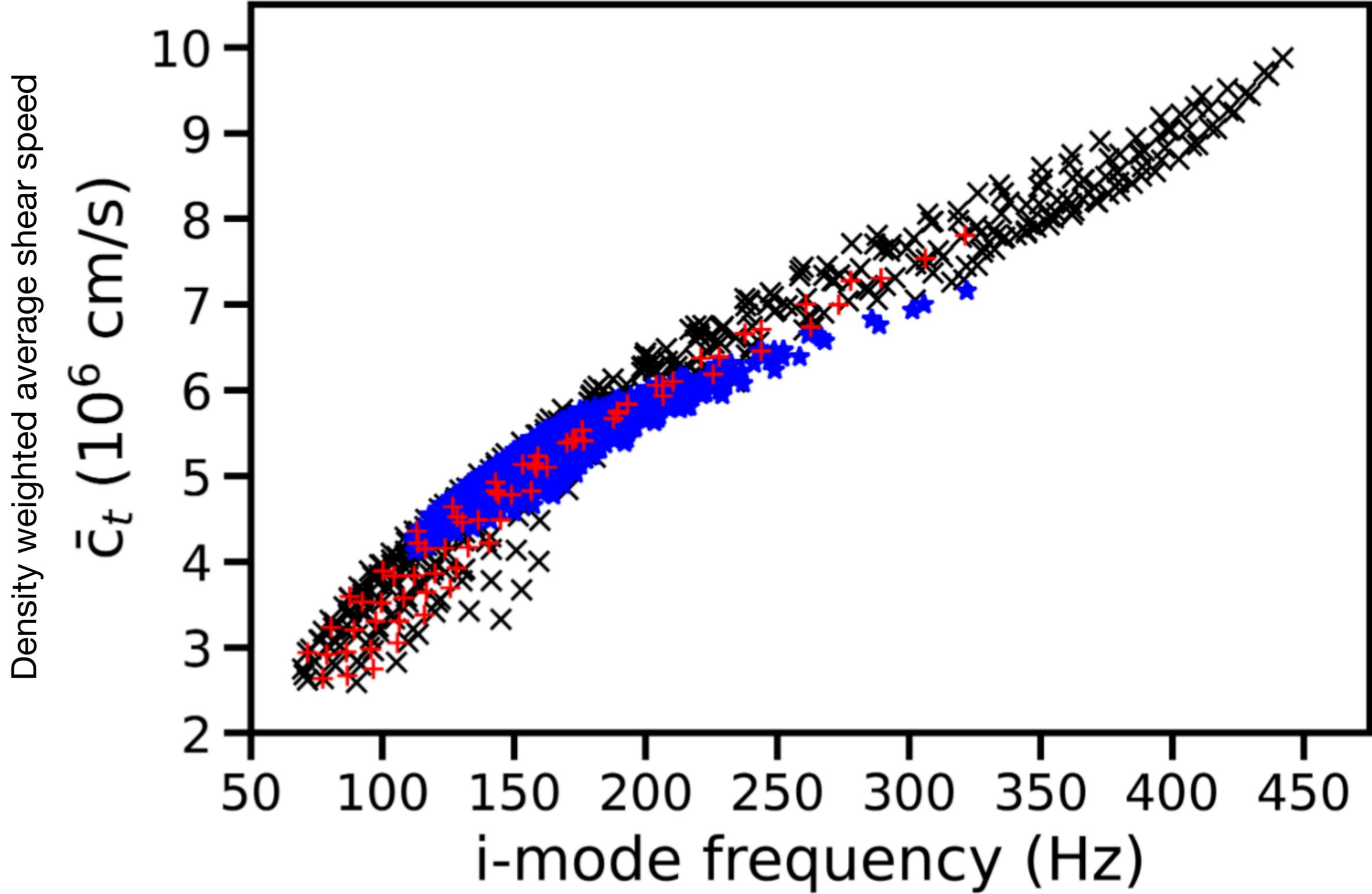


DT, et al. (2012) PRL 108, 011102

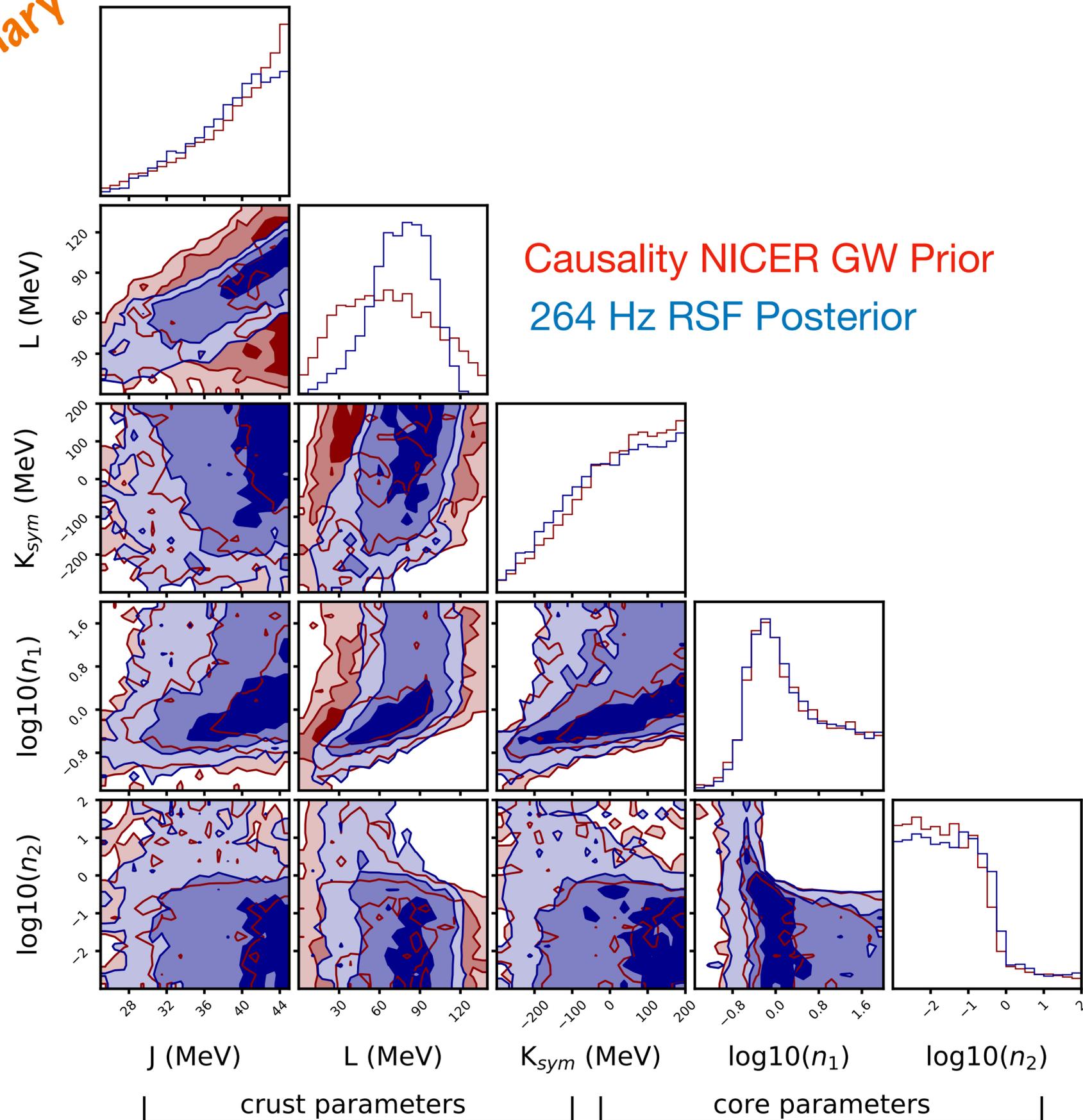
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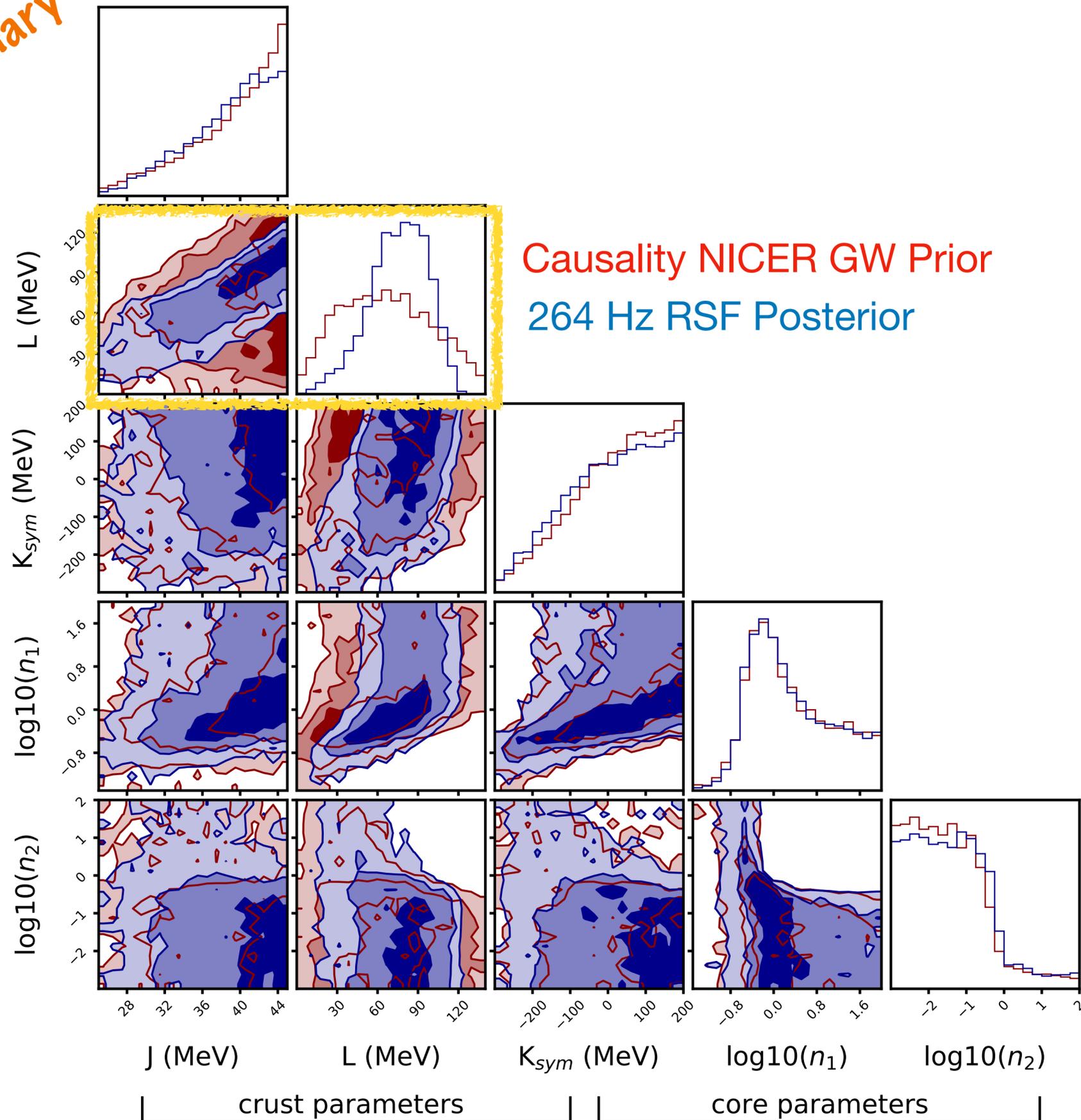




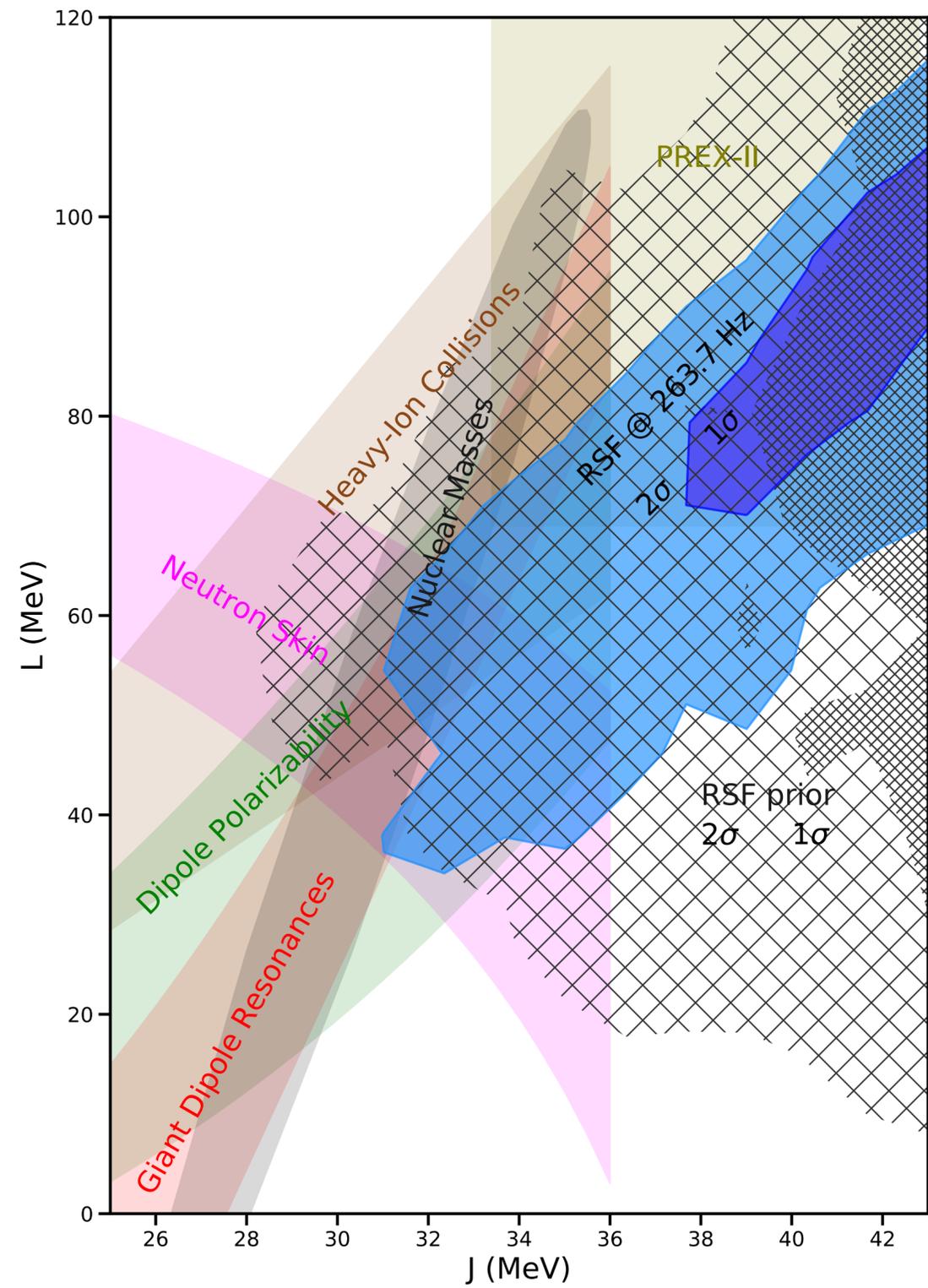
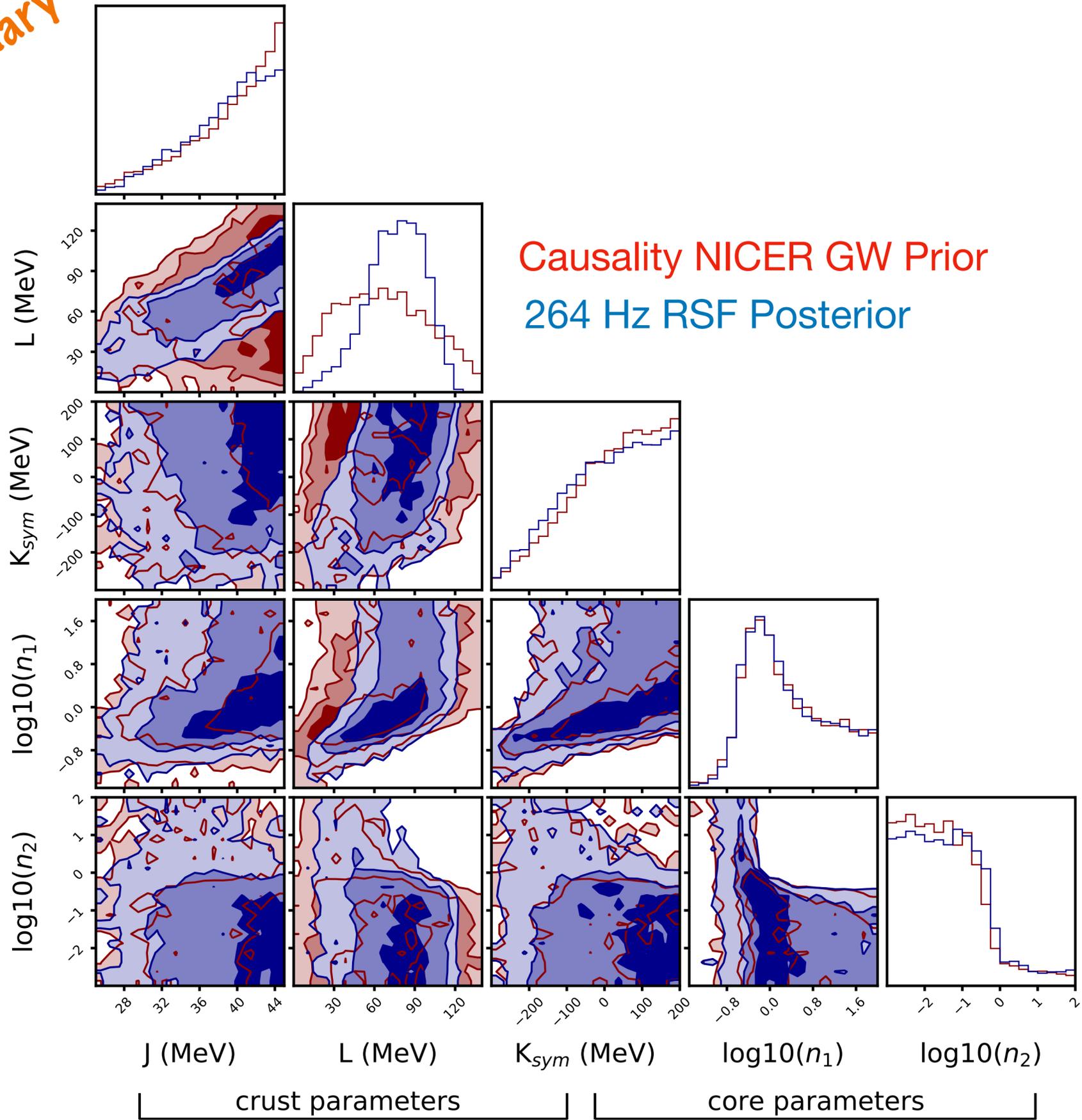
Preliminary



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Preliminary

