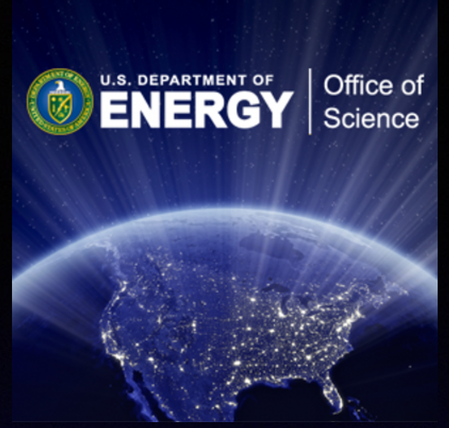


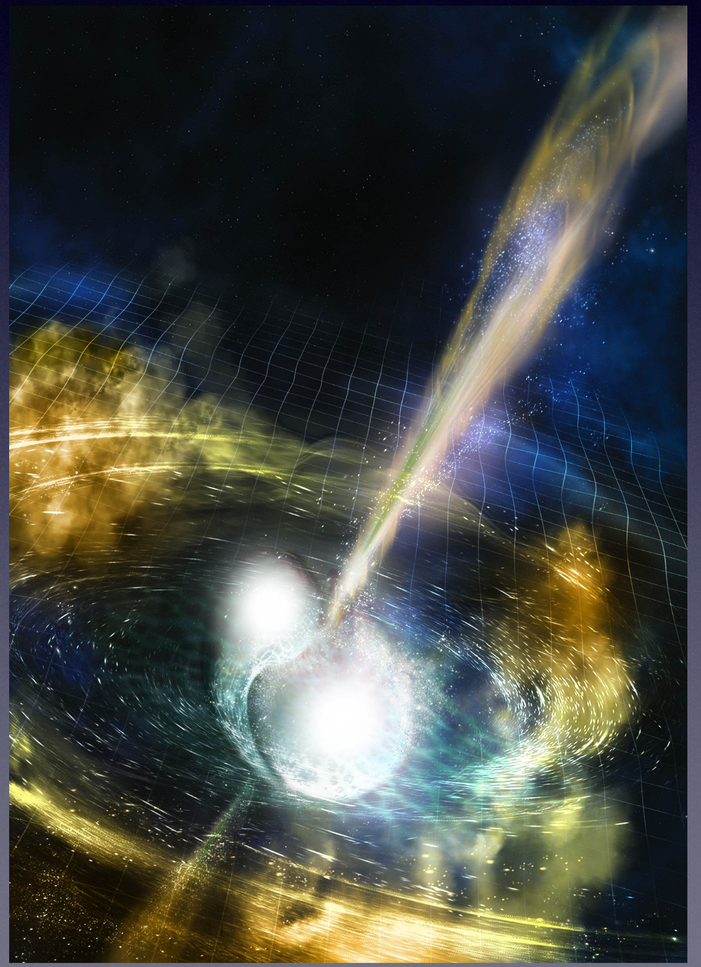
WELCOME!

INT PROGRAM INT-22-2A

Neutron Rich Matter on Heaven and Earth

July 11, 2022 - July 22, 2022

Anna Watts
Katerina Chatziioannou
Jorge Piekarewicz



Challenges and Opportunities

The INT-22-2a program on "Neutron Rich Matter on Heaven and Earth" is truly multidisciplinary as it addresses fundamental questions in fields as diverse as astrophysics, gravitational physics, nuclear physics, and particle physics.

We hope that all participants — especially students and early career scientists — be fully engaged. We ask everyone that asks a question for the first time, to identify themselves, to mention their home institution, and their main research area.

"My" Morning Speakers

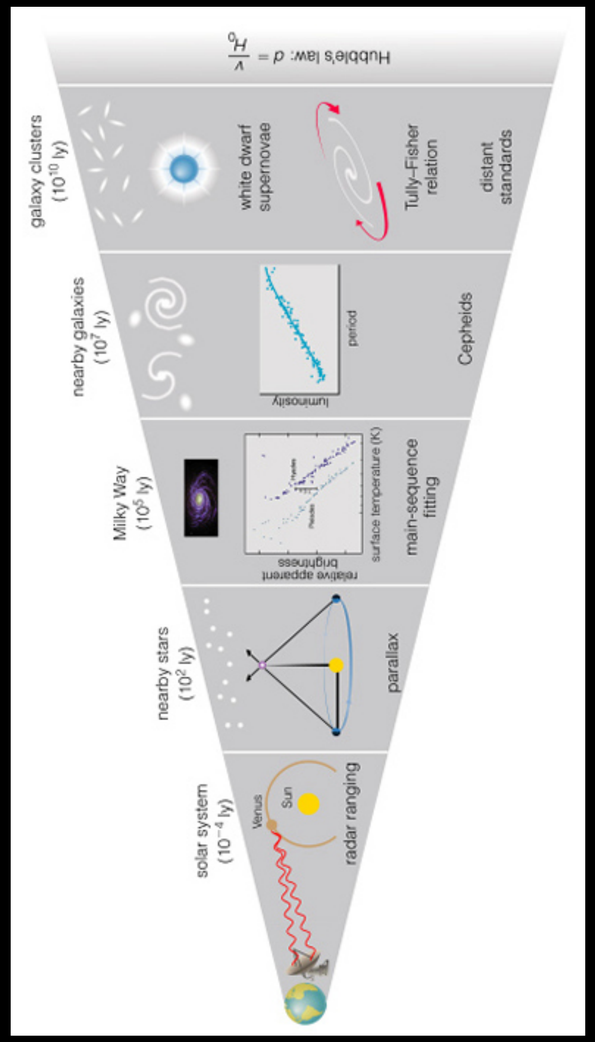
50+20 minute overview talks that address some of the most important developments in constraining the dynamics of neutron-rich matter from laboratory experiments. Please place these developments in the larger context of the equation of state of neutron-rich matter and its impact on neutron-star observables, particularly those of interest to the electromagnetic- and gravitational-wave communities.

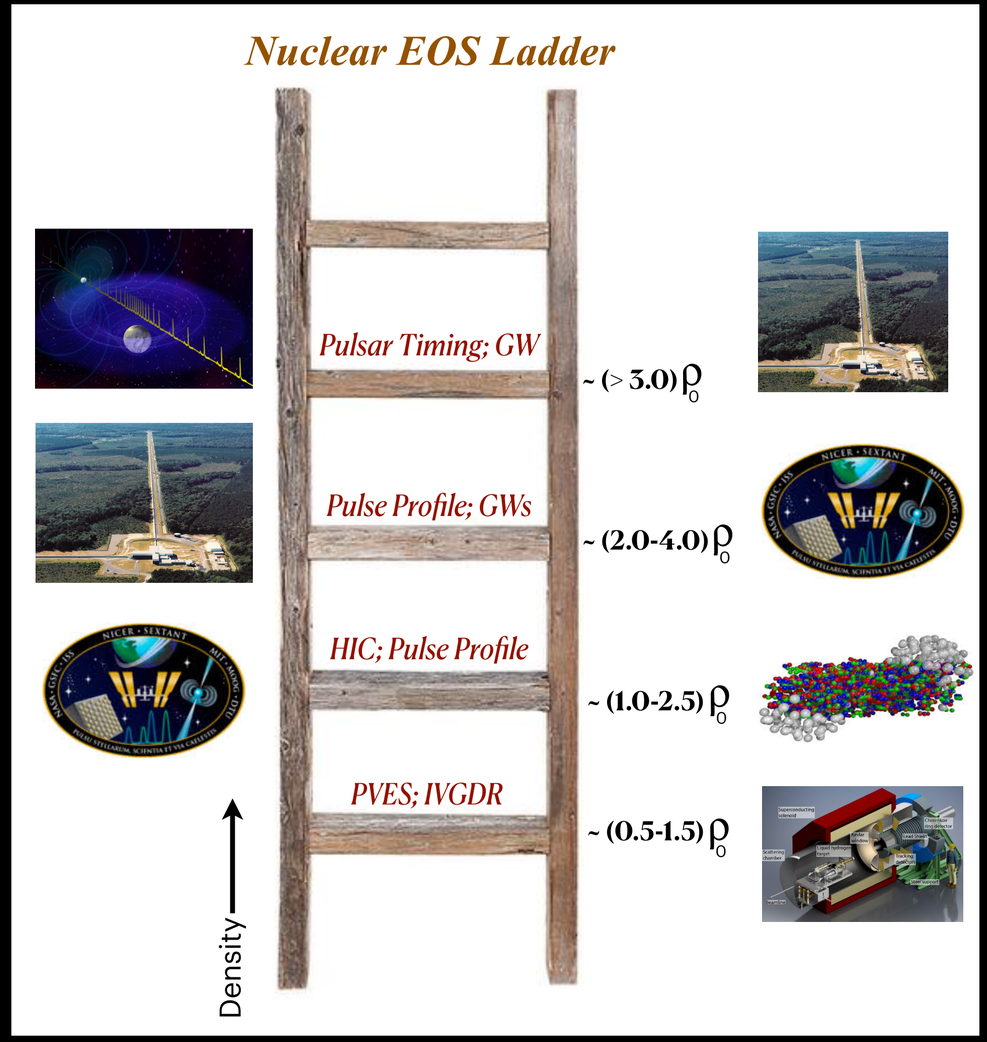
Afternoon Speakers

Short presentations, discussions and interactions, with each consisting of a 10-minute presentation **(no more than 3 slides please!)** plus up to 20 minutes of discussion. The speaker will lead the discussion, focusing on topics that are well aligned with the theme of the program; e.g., what can you offer, what are some of the main challenges and how can the "other" communities help mitigate them.

The Nuclear Equation of State

Cosmic Distance Ladder



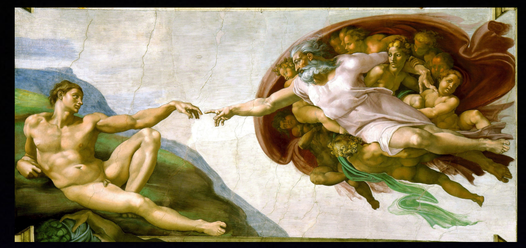


Nuclear EOS Density Ladder

The **EOS** ladder has "rungs" of objects with certain properties that let scientists confidently measure the **EOS**. Jumping to each subsequent rung relies on methods for measuring objects that are ever **denser**, the next step often piggybacking on the previous one.

Many communities working towards a common goal!

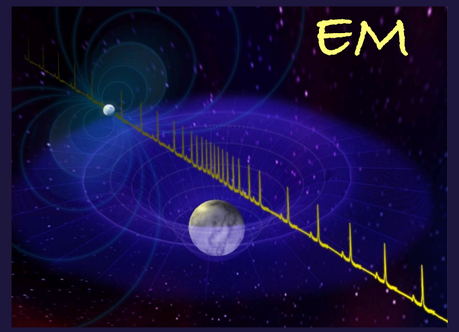
The Quest for the EOS: Status After GW170817



Heaven and Earth

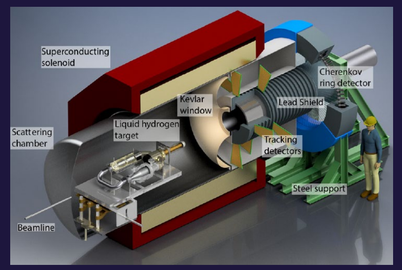
- *GW170817:* first detection of Gravitational Waves from a binary neutron-star merger
  (A gold-plated event!)
- *GW190425*: second detection of BNS
  (Hanford offline; no sky localization)
- *GW190814*: BNS or NSBH merger?
  (2.6 M_{sun} heaviest NS or lightest BH?)

- *J0740+6620*: Most massive star (2019)
  (2.14 M_{sun} — Thankful Cromartie et al)
- *J0030+0451:* NICER aboard the ISS (2019)
  (First ever mass-radius determination)



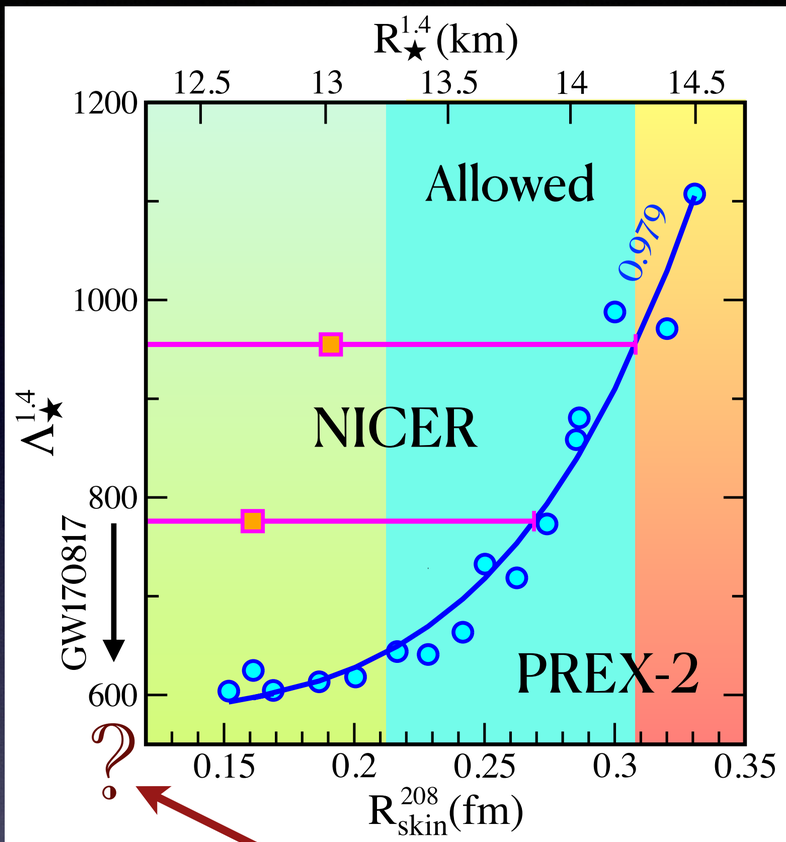
- *PREX-II:* Neutron-skin thickness of ^{208}Pb
  (Suggests the skin is large and the EOS stiff)

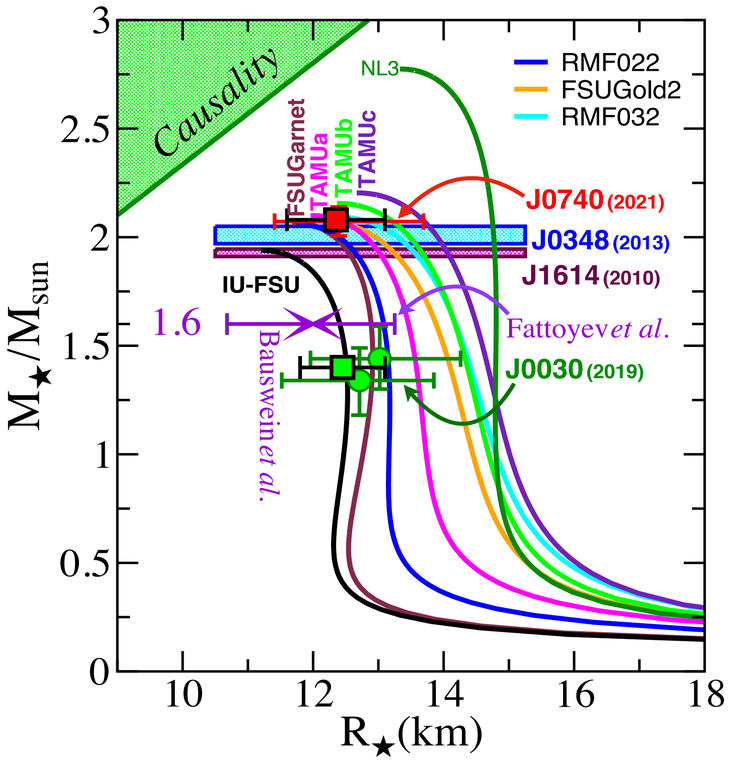
Terrestrial experiments

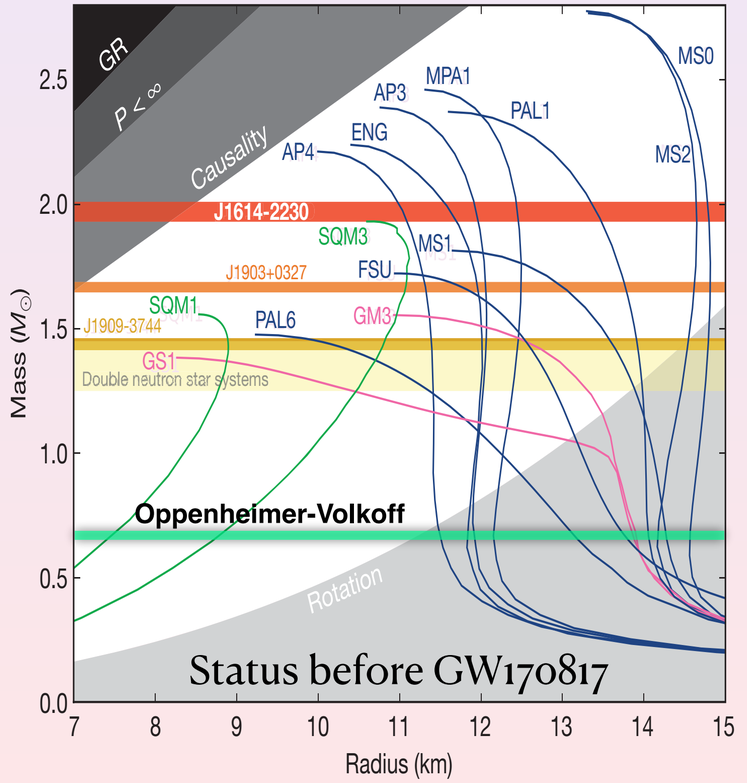


Powerful synergy developing between terrestrial experiments, electromagnetic observations, and gravitational-wave detections:
A brand new era of Multimessenger Astronomy!

The dawn of the golden era in neutron-star physics







Tantalizing Possibility

- *Laboratory Experiments suggest large neutron radii for Pb* $\lesssim 1\rho_0$
- *Gravitational Waves suggest small stellar radii* $\gtrsim 2\rho_0$
- *Electromagnetic Observations suggest large stellar masses* $\gtrsim 4\rho_0$

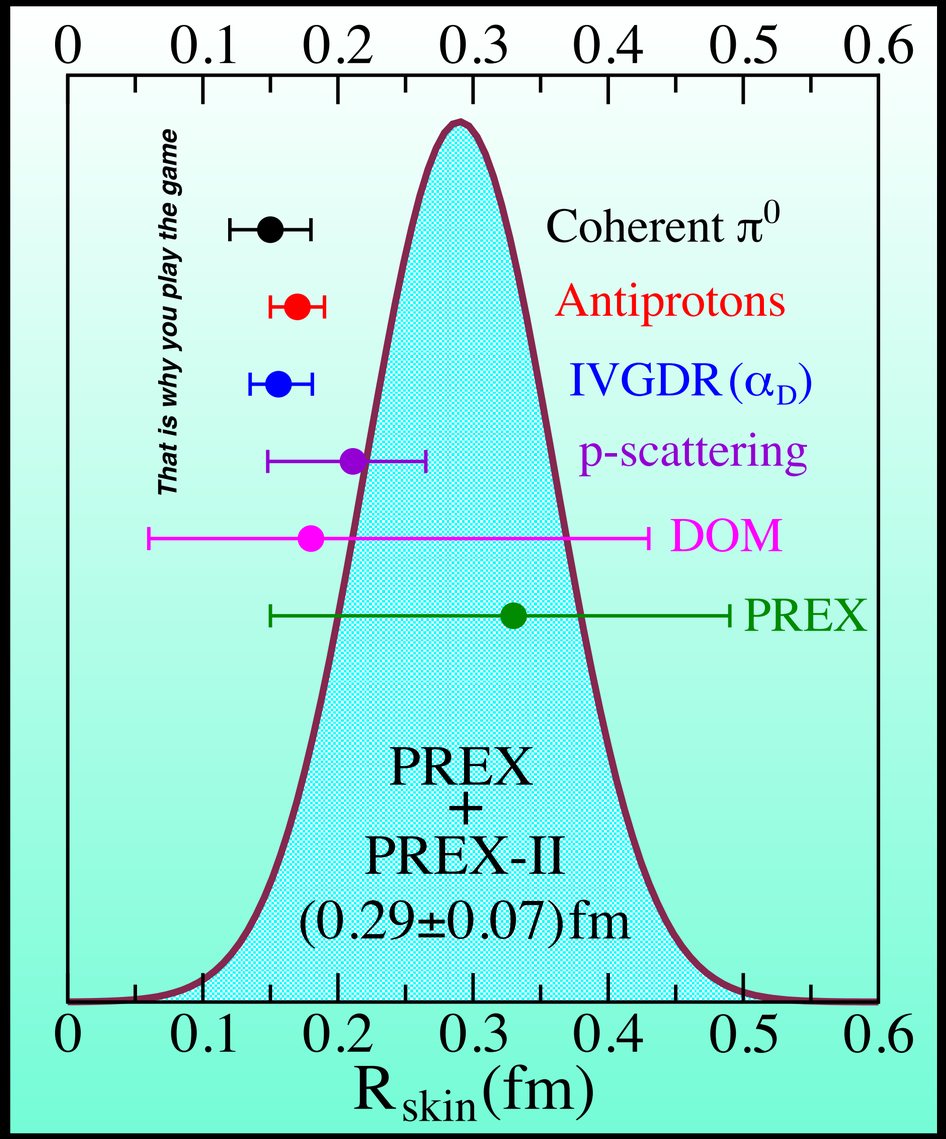
Exciting possibility: If all are confirmed, this tension may be evidence of a softening/stiffening of the EOS (phase transition?)

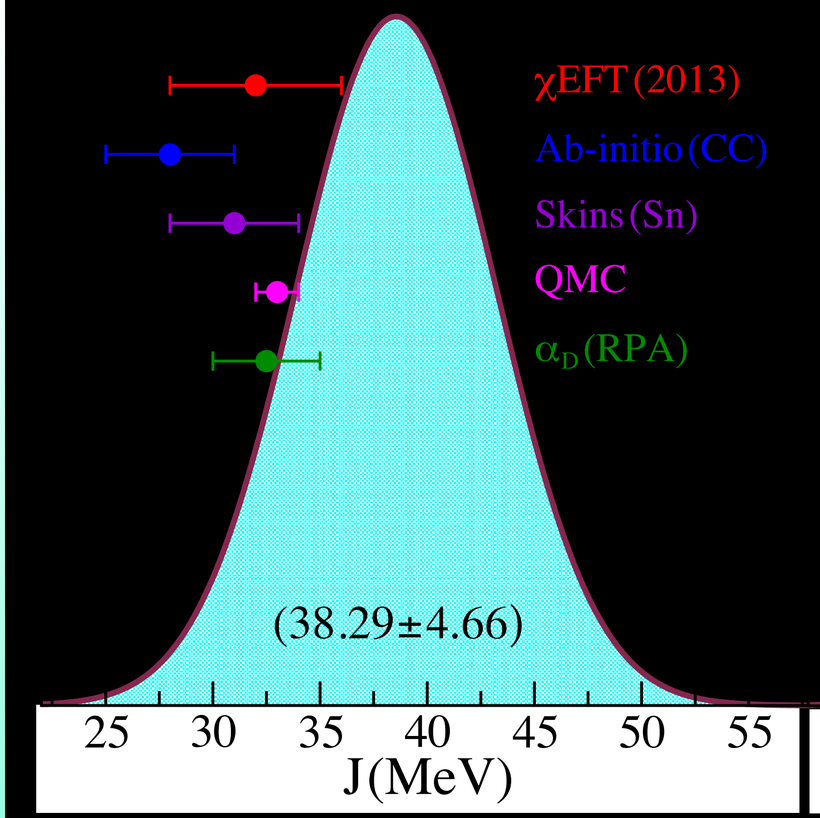
Extraordinary claims require extraordinary evidence!

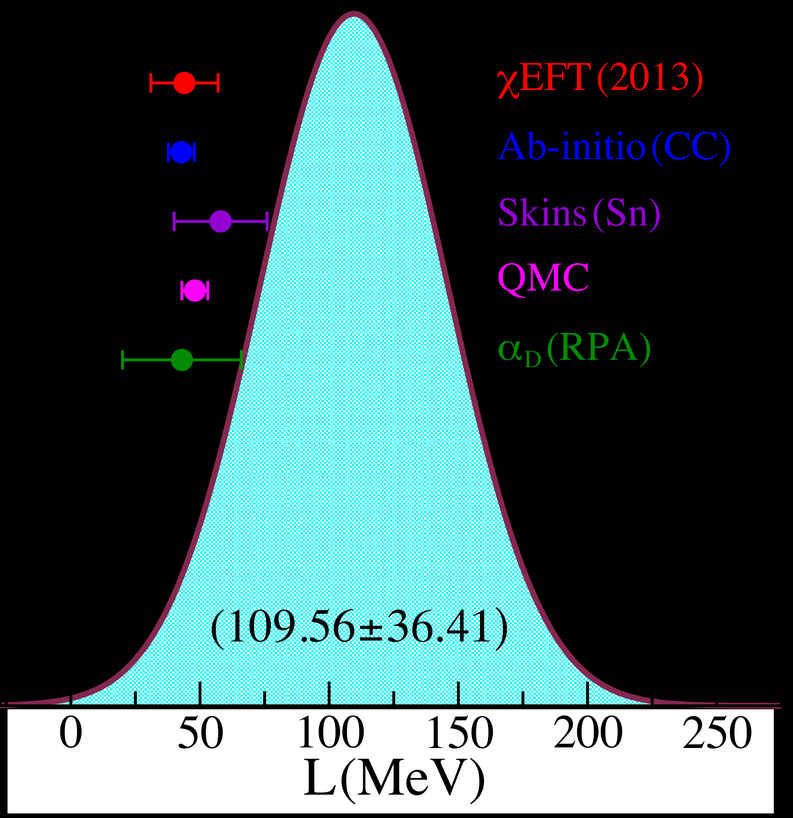
Need to understand the "ins-and-outs" of the extraction and uncertainty quantification of the tidal deformability!

PREX Constraints on the EOS of Neutron Rich Matter

$$L \approx P_{\mathrm{PNM}}(n_0)$$



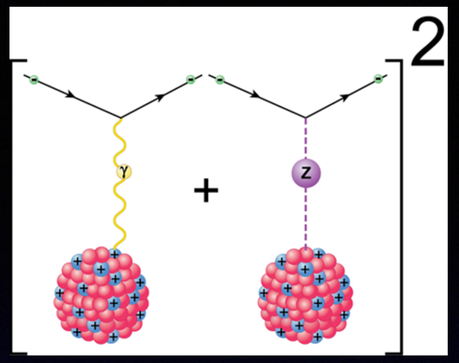


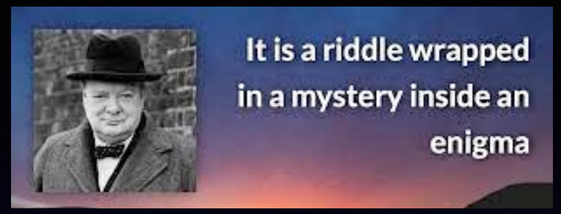


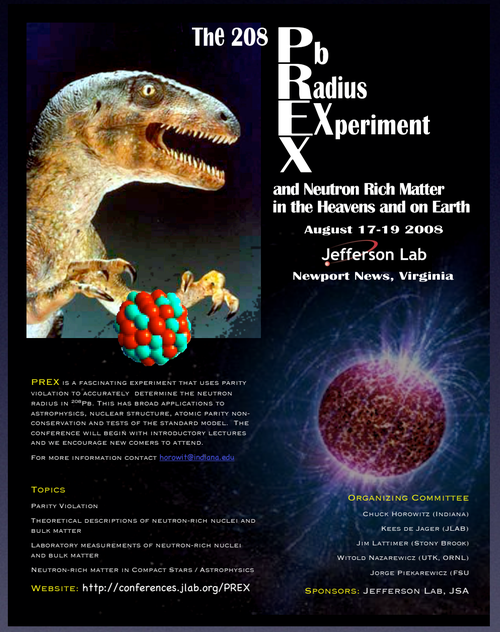
PREX suggests that L is large — suggesting (at lease in some models!) that neutron-star radii should also be large!

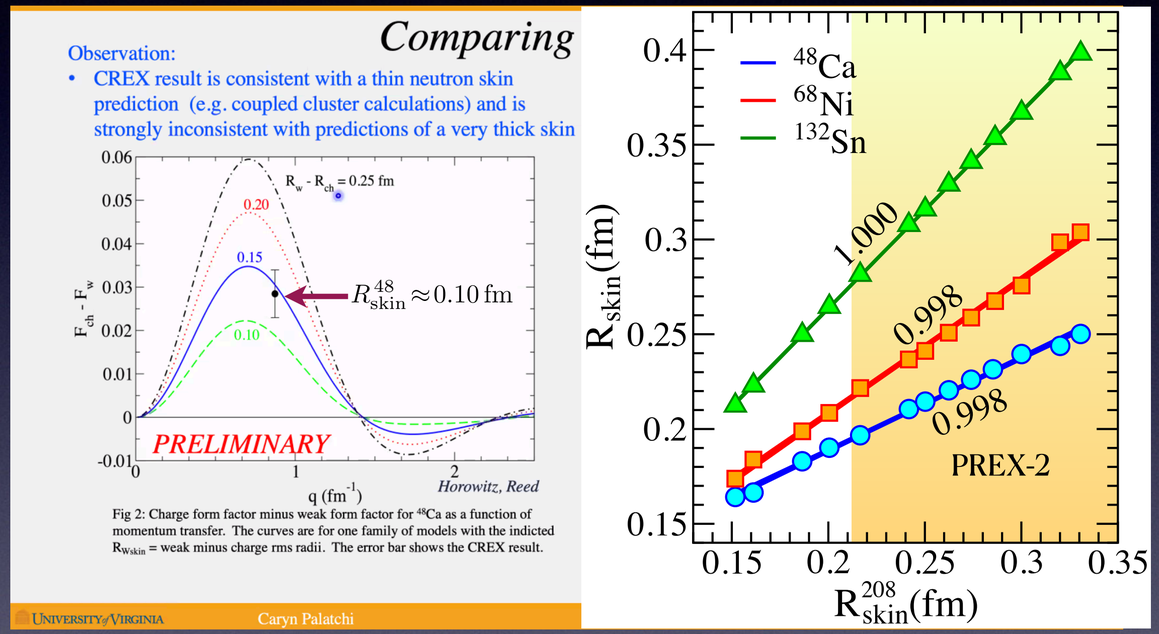
Parity Violating e-Nucleus Scattering

Correlating the neutron skin to the EOS









$R^{208}_{\rm skin} = (0.283 \pm 0.071)$ fm

PREX-2021: L is BIG!

$R^{48}_{\rm skin} = (0.121 \pm 0.035)$ fm

CREX-2022: L is SMALL!

Electroweak experiments will provide fundamental anchors for future campaigns at FRIB and other exotic beam facilities; so we better work hard on solving the riddle …

What can I offer:

Predictions of neutron-star properties derived from accurately-calibrated models

What is the challenge:

Apparent inconsistency of PREX and CREX

How can the challenge be mitigated:

Determination of stellar radii with a precision of 0.5 km