

# Goals of ICNT Program: Symmetry Energy in the Context of New Radioactive Beam Facilities and Astrophysics

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# Symmetry Energy $S$

- Describes how energy of system rises as one goes away from equal numbers of neutrons and protons.
- Interested in  $S$  at low density ( $<0.3n_0$ ) where matter may be nonuniform, at medium density ( $0.3n_0$  to  $n_0$ ) important for nuclear structure, and at high density ( $>n_0$ ).
- ***Measuring  $S$  at high density is the single laboratory observable most closely related to the structure of neutron stars.***

# Program Goals are three fold

- **Dense QCD**: learn about the phases of dense QCD
- **Communication**: improve communication between nuclear physicists and astrophysicists and between new and established groups of Americans, Japanese, Koreans, Chinese, Europeans ... working on the symmetry energy.
- **A way forward**: identify the most important experiments, calculations, and astrophysical observations to do to improve our knowledge of S. In particular, *what are future experiments or theoretical developments for FRIB.*

# Dense QCD

- What are neutron stars made of? neutrons, hyperons, quarks...
- We do not know how to calculate at high densities! **Only options** to study dense matter: experiments with HI collisions or astronomical observations.
- Important to combine lab. exp with astronomical observations.

# Communication

- In both astrophysics and the lab it is the same neutrons, the same strong interactions, and the same equation of state. A measurement in one domain (astrophysics or the lab) can have important implications in the other.
- Need to explain to the astronomers what we are doing (and vice versa) in a way they understand **and believe!**
- Can astronomers explain to us the motivation for expensive X-ray missions!?
- Exciting recent new efforts on symmetry energy in many areas of the world. We should work to improve communication between existing and new efforts.
- The rate our field advances is determined by our ability to communicate.

# A way forward: a plan for the symmetry energy

- Identify the best observables to be measured, that give  $S$  at high densities, **with the cleanest theoretical interpretations.**
- Identify the most important astronomical observations related to  $S$ , with the cleanest theoretical interpretations.
- It is all about the theoretical errors! How can we minimize model dependence in extracting  $S$ .

# HOMEWORK: Required!

- Each of you is REQUIRED to (1) have an opinion about the way forward and (2) email this opinion to me ([horowitz@indiana.edu](mailto:horowitz@indiana.edu)) by the end of the week.
- Examples: “I liked Alice’s talk on tuesday”, “We need to measure neutron differential flow at high energies ...”, “What I do is the only way forward because...”
- We will write up these comments into some kind of a collected document during the fourth week of the program.

# Subgoals

- Definition of symmetry energy. Second derivative with respect to proton fraction evaluated a
- Eat in all of the “good” restaurants in East Lansing. Please list... Sultans, Sansu (sushi), Pizza House, Old Chicago, Dusty’s Cellar, Maru ...
- What one thing would you like astrophysicists to take away from your nuclear physics talk (or vice versa) “The Bob question”