Main points

EOS is **well constrained by ab initio calculations** for

Neutron-rich conditions and nondegenerate conditions

especially interesting for mergers!

General EOS band based on nuclear physics and observations

neutron star radius 9.7-13.9 km for $M=1.4\ M_{sun}$ (±15%)

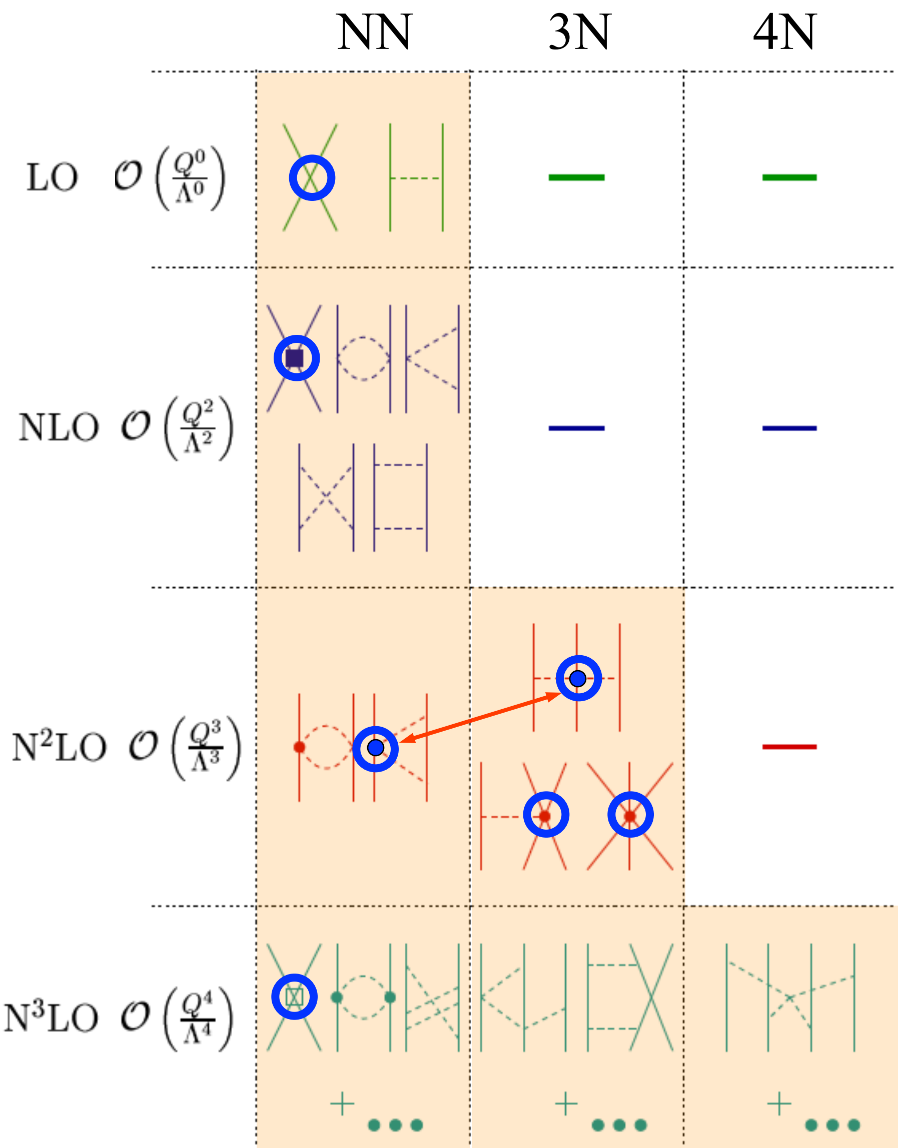
Chiral EFT important for consistent neutrino-matter interactions

Enhancement of neutrino bremsstrahlung at low densities

with A. Bartl, C. Drischler, K. Hebeler, T. Krüger, J. Lattimer, C. Pethick, V. Soma, I. Tews

Chiral effective field theory for nuclear forces

Separation of scales: low momenta $\frac{1}{\lambda} = Q \ll \Lambda_b$ breakdown scale ~500 MeV



include long-range pion physics

few short-range couplings,
fit to experiment once

systematic: can work to desired accuracy and obtain **error estimates**

consistent **electroweak interactions** and **matching to lattice QCD**

Weinberg, van Kolck, Kaplan, Savage, Wise, Bernard, Epelbaum, Kaiser, Machleidt, Meissner,…

Frontier of ab-initio calculations at A~50

doi:10.1038/nature12226

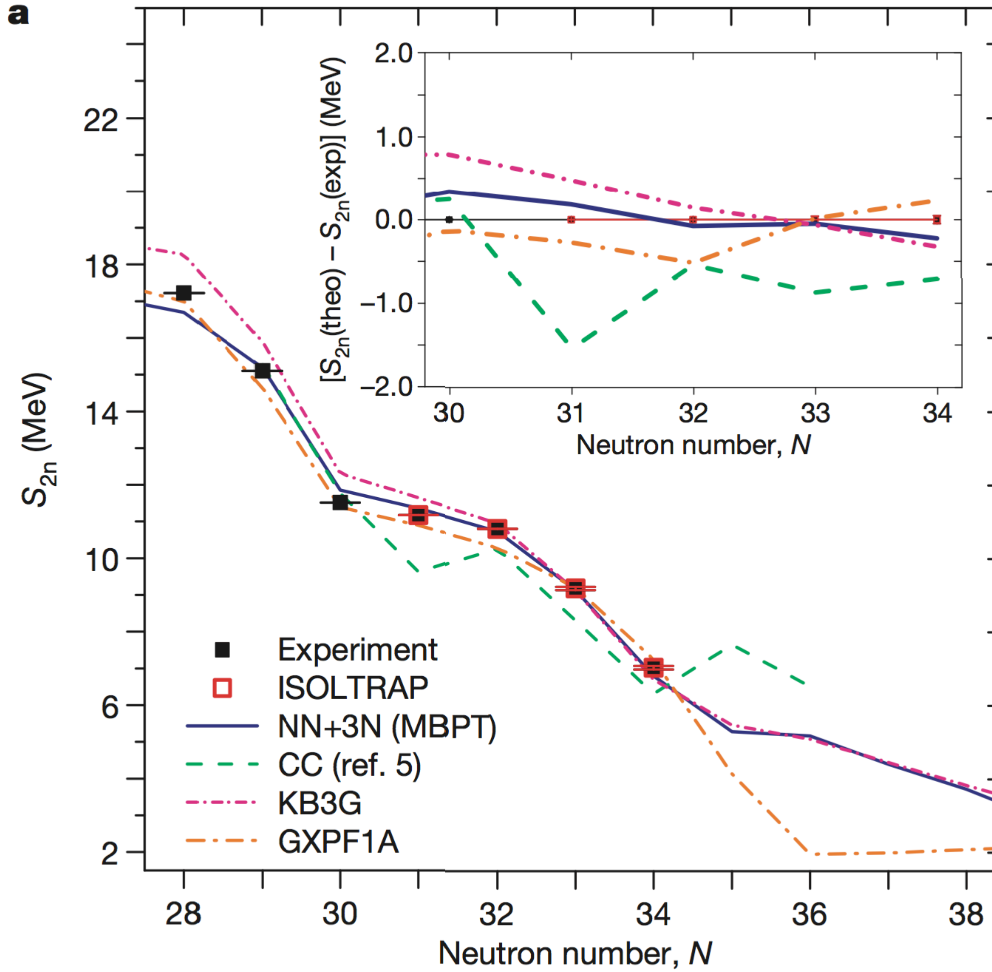
Masses of exotic calcium isotopes pin down nuclear forces

F. Wienholtz[1], D. Beck[2], K. Blaum[3], Ch. Borgmann[3], M. Breitenfeldt[4], R. B. Cakirli[3,5], S. George[1], F. Herfurth[2], J. D. Holt[6,7], M. Kowalska[8], S. Kreim[3,8], D. Lunney[9], V. Manea[9], J. Menéndez[6,7], D. Neidherr[2], M. Rosenbusch[1], L. Schweikhard[1], A. Schwenk[7,6], J. Simonis[6,7], J. Stanja[10], R. N. Wolf[1] & K. Zuber[10]

^{53,54}Ca masses measured at ISOLTRAP using new MR-TOF mass spectrometer

establish prominent N=32 shell closure in calcium

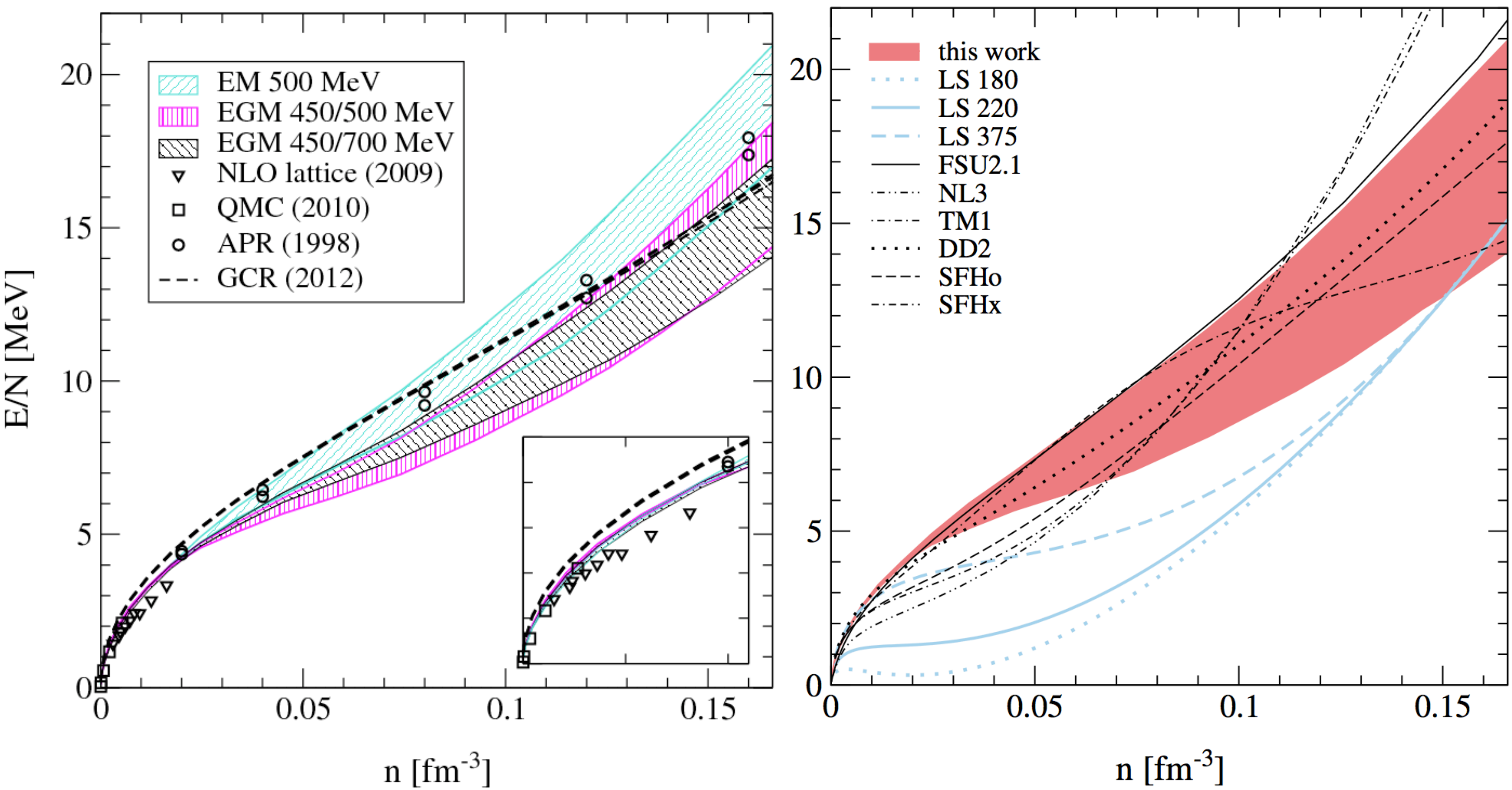
excellent agreement with theoretical NN+3N prediction



Complete N^{3}LO calculation of neutron matter

first complete N^{3}LO result **Tews, Krüger**, Hebeler, AS (2013)

includes uncertainties from NN, 3N (dominates), 4N

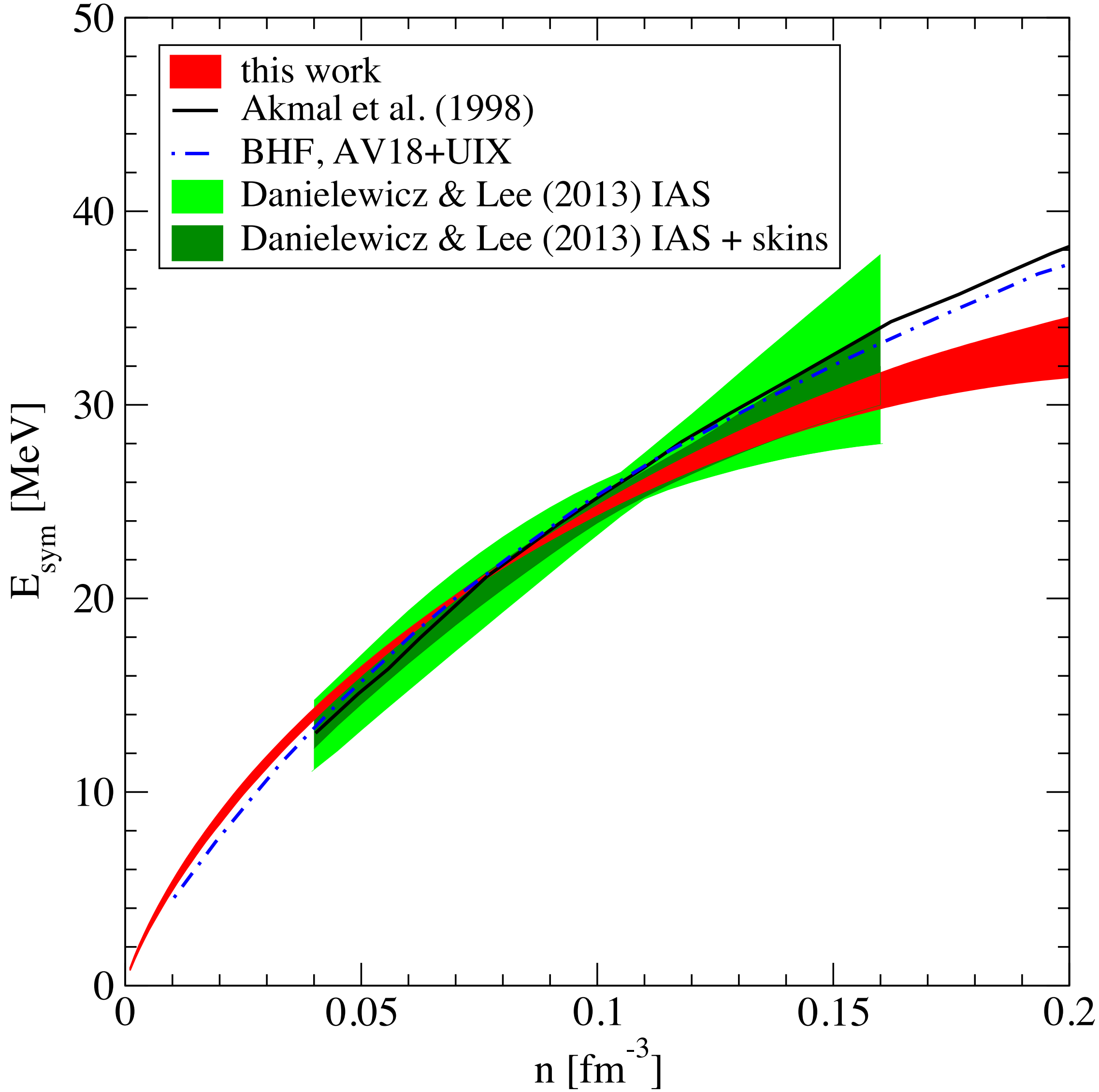


many EOS used in simulations not consistent with neutron matter results

Calculations of asymmetric matter Drischler, Soma, AS, PRD (2014)

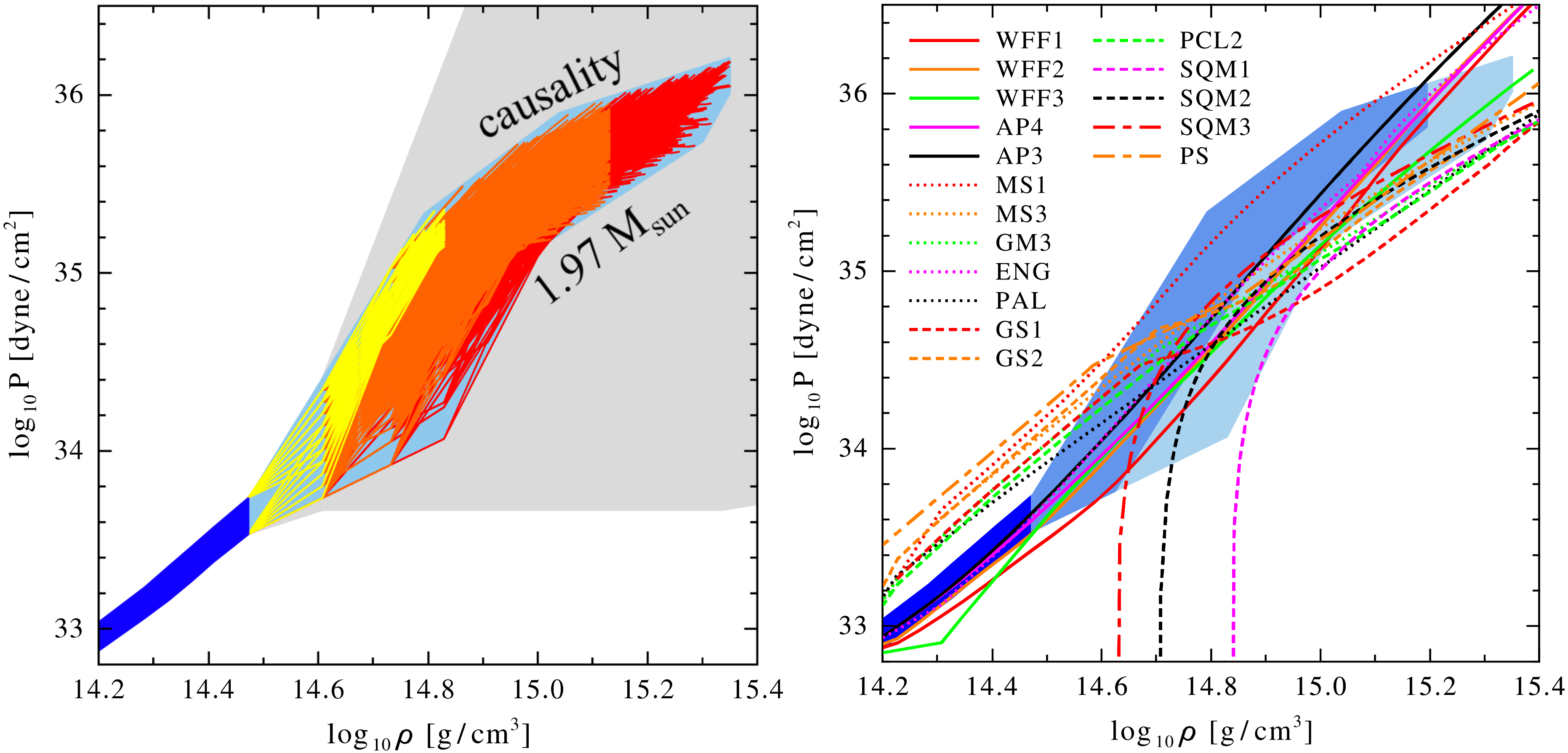
E_{sym} comparison with extraction from isobaric analogue states (IAS)

3N forces fit to ^3H, ^4He properties only



Pressure of neutron star matter

constrain polytropes by causality and require to support 1.97 M_{sun} star



low-density pressure sets scale, chiral EFT interactions provide strong constraints, ruling out many model equations of state

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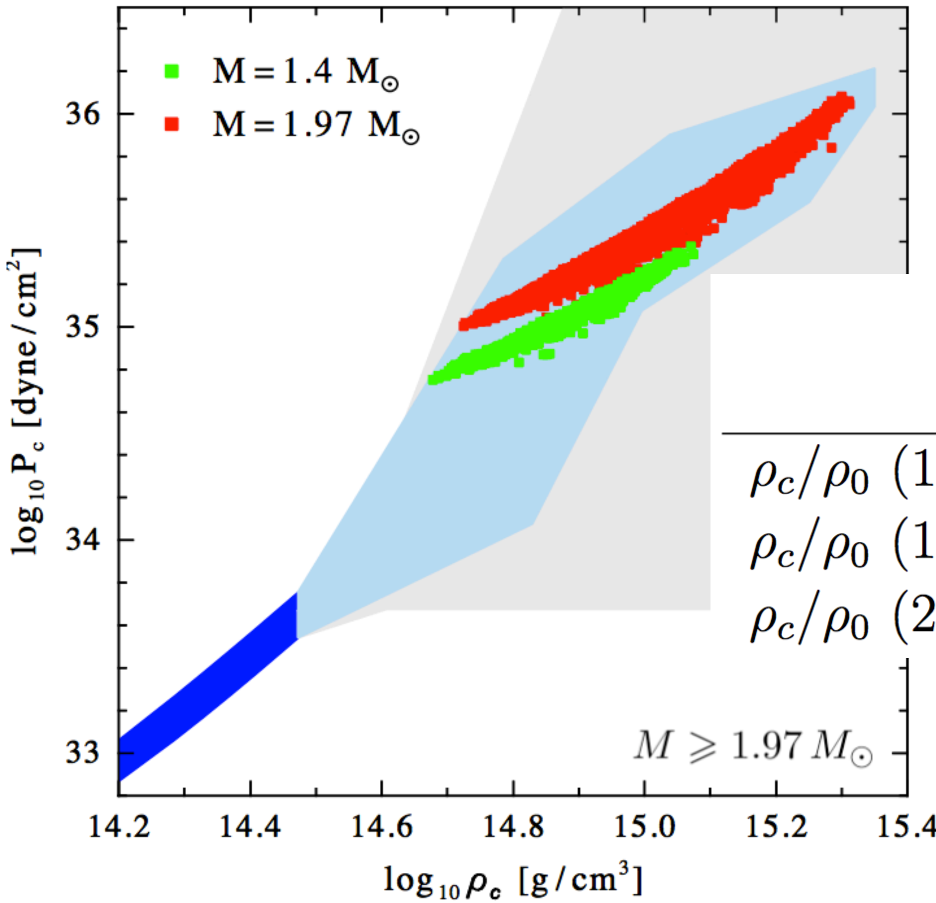


	$\widehat{M} = 1.97\, M_\odot$		$\widehat{M} = 2.4\, M_\odot$	
	min	max	min	max
$\rho_c/\rho_0\ (1.4\, M_\odot)$	1.8	4.4	1.8	2.7
$\rho_c/\rho_0\ (1.97\, M_\odot)$	2.0	7.6	2.0	3.4
$\rho_c/\rho_0\ (2.4\, M_\odot)$			2.2	5.4

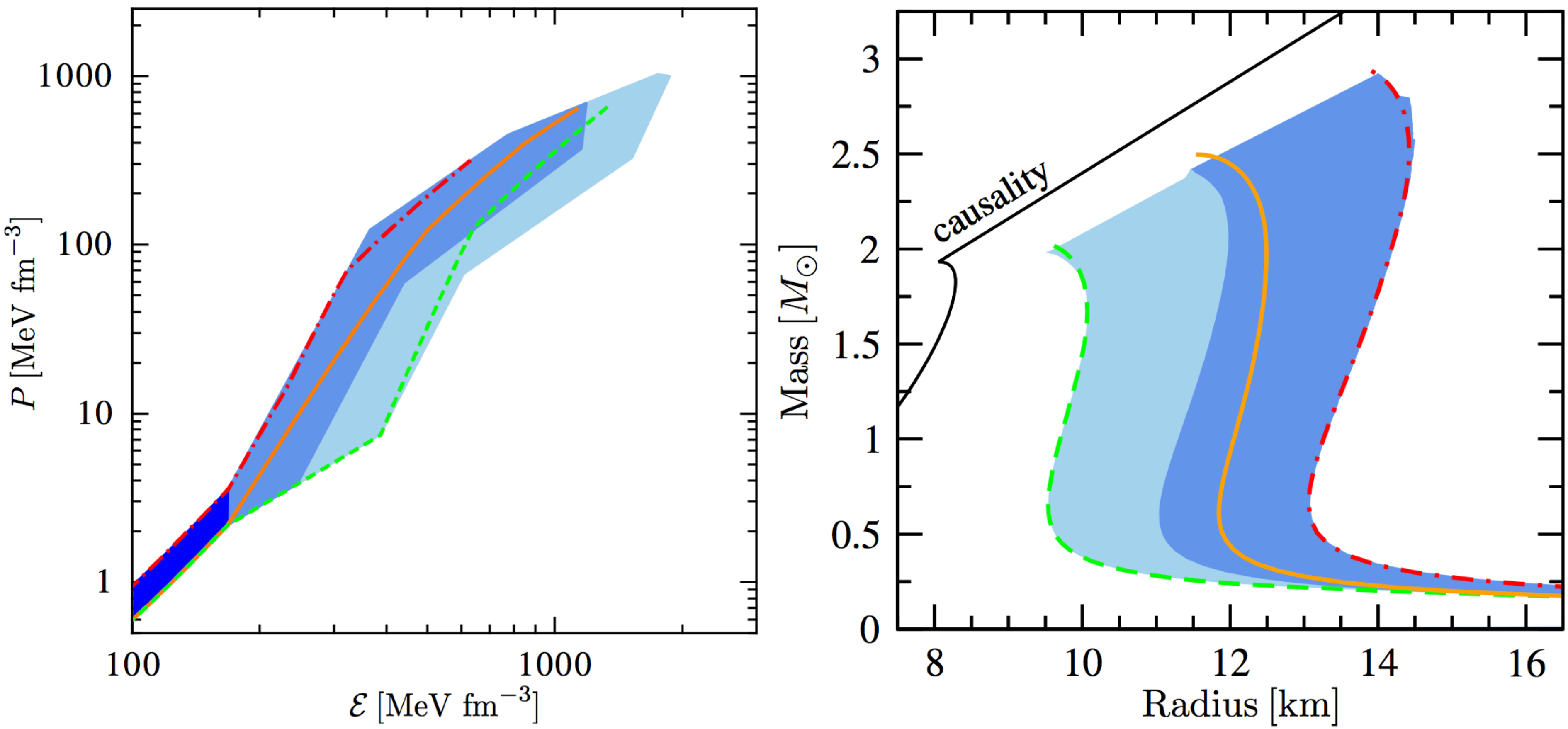
low-density pressure sets scale, chiral EFT interactions provide strong constraints, ruling out many model equations of state

central densities for 1.4 M_{sun} star: 1.8-4.4 ρ_0

Representative equations of state

all EOS for cold matter in beta equilibrium should go through our band

constructed 3 representative EOS for users: soft, intermediate, stiff

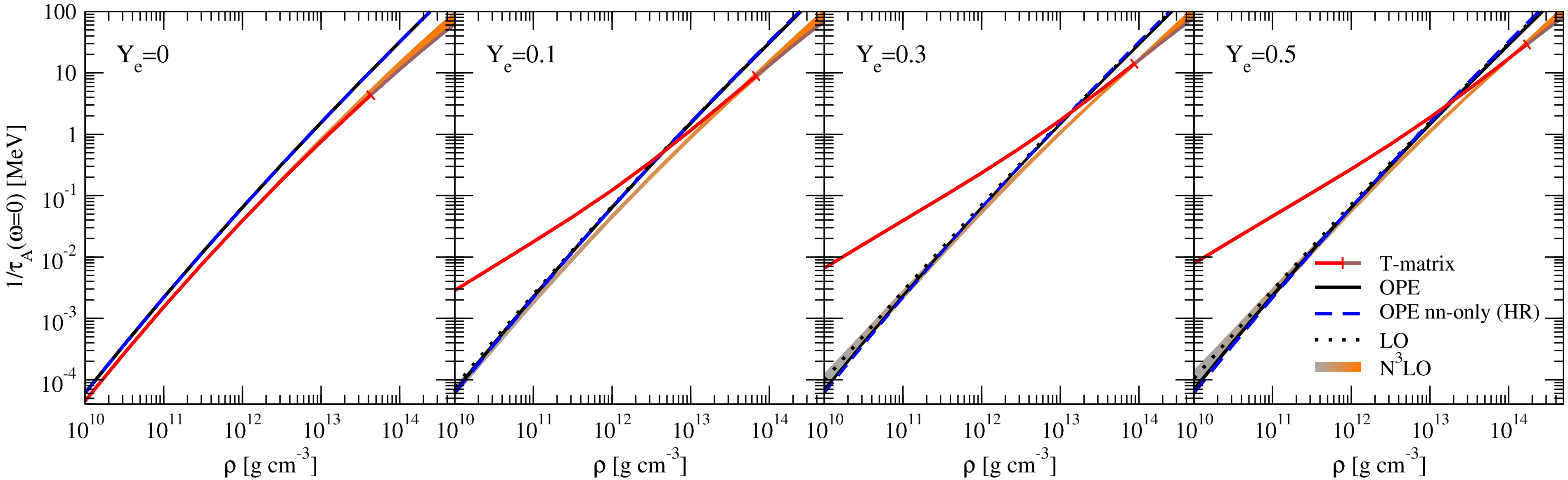


Neutrino bremsstrahlung in mixtures of neutron and protons

in mixtures also S-wave interactions enter: large scattering lengths!

lead to enhancement of bremsstrahlung at low densities for nonzero Y_e

Bartl, Pethick, AS, PRL (2014)



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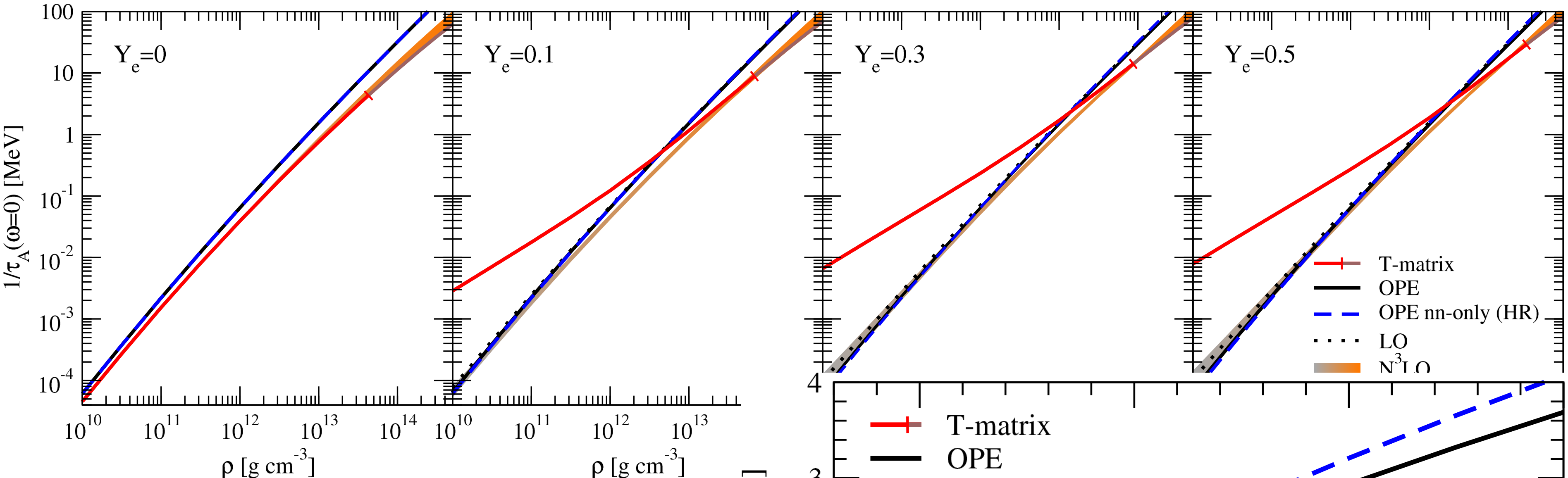

same enhancement at low T