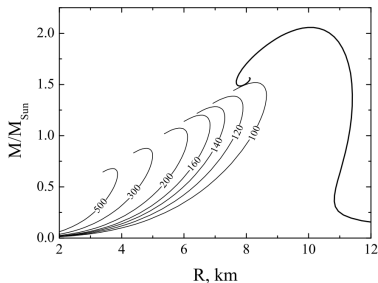
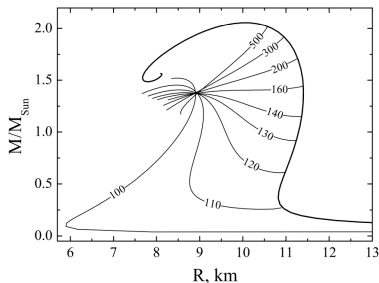




## Single-phase neutron stars



## Hybrid neutron stars

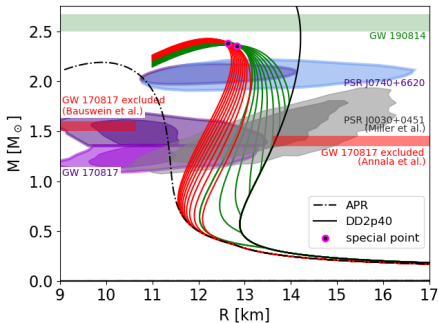
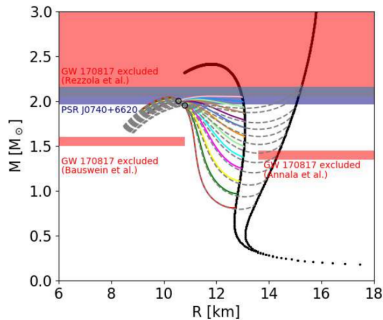


The special point is a unique property of hybrid neutron stars. The mass–radius relations of such stars will always include a specific narrow region regardless of the choice of a phase transition onset density (illustrated on the right figure). We find the location of this region to be largely insensitive to the choice of the low density equation of state and explore the possible implications on the likelihood of observing hybrid stars using current multi–messenger methods.

Figure origin: Yudin, et al., *Astron.Lett.* 40 (2014), 201, arXiv: 1404.0865

CSS quark model: Alford, et al., *Phys. Rev. D* 88 (2013), 083013, arXiv: 1302.4732

## The special point invariance.



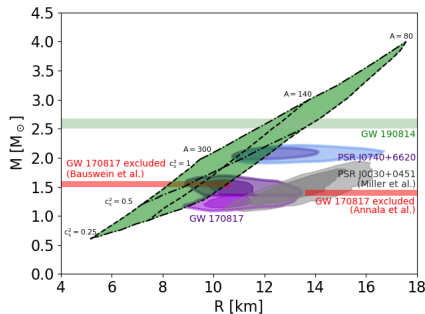
The special point location in the mass–radius plane remains largely insensitive to its low density hadronic part (left figure). We find it also approximately invariant to the choice of a phase transition construction (right figure). Source for the phase transition constructions will be shown on the next slide.

Left figure origin: M.C., D.B., Eur.Phys.J.ST 229 (2020) 22-23, 3663-3673, arXiv: 2009.12353

Right figure origin: M.C., D.B., Astron.Nachr. 342 (2021) 5, 819-825, arXiv: 2106.06986



## The special point mass–radius map.



$c_s^2$	$M_{\text{SP}}$ [ $M_{\odot}$ ]	$R_{\text{min}}$ [km]	$R_{\text{max}}$ [km]
0.35	1.82	-	-
0.40	2.07	12.18	12.29
0.45	2.30	11.84	13.41
0.50	2.50	11.56	13.91
0.55	2.68	11.30	14.20
0.60	2.86	11.05	14.45
0.70	3.22	10.67	14.67
1.00	4.00	9.95	14.84

We performed a detailed mapping of the special point location for different model parameters of the CSS quark model. The map was used to derive the range of possible radii of a hybrid star with mass similar to PSR J0740+6620.



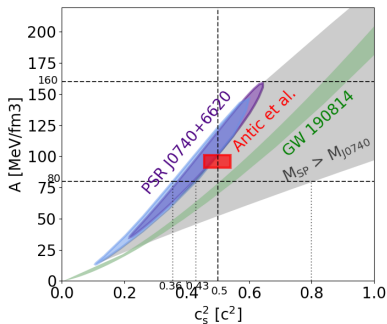
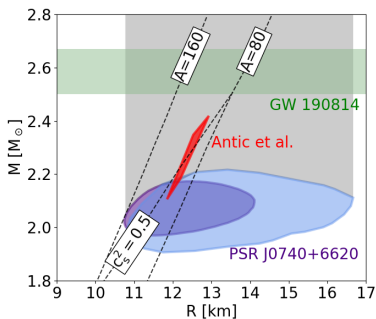
Figure and table origin: M.C., D.B., *Astron.Nachr.* 342 (2021) 5, 819-825, arXiv: 2106.06986

Parabolic phase transition (previous slide): Abgaryan, et al., *Universe* 4 (2018) 9, 94, arXiv: 1807.08034





Connection to the the microscopic nINJL quark matter model.



Assuming the limiting case that the special point mass is equal to the maximum mass, observational constraints can be translated directly as model parameter limits.



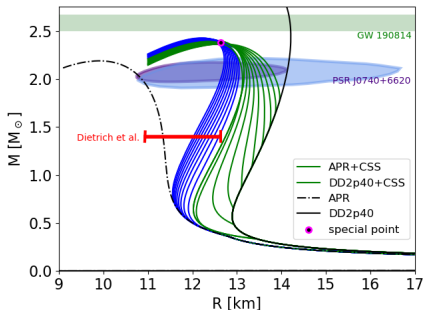
Figure origin: M.C., D.B., EPJ Web Conf. 258 (2022), 07009, arXiv: 2112.09166

CSS fit to the nINJL model: Antic, et al., (2021), arXiv: 2105.00029





## Conclusions and outlook.



- ▶ The special point allows to study hybrid stars independently of the hadronic equation of state
- ▶ Applications to studies of quark matter properties has been demonstrated, further efforts are ongoing.
- ▶ Relation between the special point and hybrid star tidal deformability remains unexplored.



Additional special point study: D.B., M.C., Astron.Nachr. 342 (2021) 1-2, 227-233, arXiv: 2012.15785

Tidal deformability radius constraint: Dietrich, et al., Science 370 (2020) 6523, 1450-1453, arXiv: 2002.11355

