Maximum mass of compact stars from gravitational wave events with finite-temperature equations of state

Micaela Oertel

micaela.oertel@obspm.fr

In collaboration with S. Khadkikar, A.R. Raduta, and A. Sedrakian

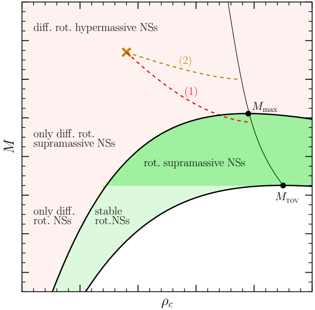
Laboratoire Univers et Théories (LUTH)
CNRS / Observatoire de Paris/ Université Paris Diderot

LVK Extreme Matter WG meeting, January 27, 2021

CONSTRAINTS ON TOV MASS FROM GW170817

- Limits on $M^\star_{\rm TOV}$ very interesting for constraining the EoS
- Measured pulsar masses give a lower limit on the maximum mass
- Different authors have extracted limits from GW170817

[Margalit & Metzger 2017, Rezzolla+2018, Shibata+ 2019, Ruiz+ 2019,...]



[Rezzolla+ 2018]

Idea :

- No prompt collapse for GW170817, but formation of a differentially rotating HMNS
- Internal viscosities lead to rigid rotation, the star collapses upon crossing the stability line for rigid rotation
- Assumption : stability line crossed close to $M^\star_K$ [Rezzolla+], limits slightly relaxed if $M < M^\star_K$ [Shibata+]
- Universal relation between $M^\star_K$ and $M^\star_{\rm TOV}$

- But the merger remnant might still be hot and (partly) out of β-equilibrium upon collapse !

Universal relations

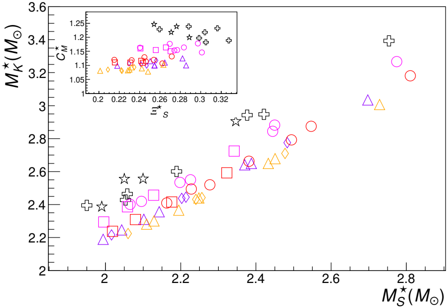
- Universality : relating star's properties independently of the EoS
- Many phenomenologically established ones for cold, β-equilibrated stars, e.g. I-Love-Q relations [Yagi & Yunes]

- Here : maximum (gravitational) mass at the Kepler limit as function of the maximum mass of the nonrotating configuration

[Cook+94,Lasota+96,Breu&Rezzolla2016]

$$M_K^\star = C_M^\star M_S^\star$$

- Valid at finite T, too, if same thermodynamical conditions are considered



- Similar findings for other relations : Kepler frequency in terms of nonrotating mass and radius, . . .

Maximum TOV mass from GW170817

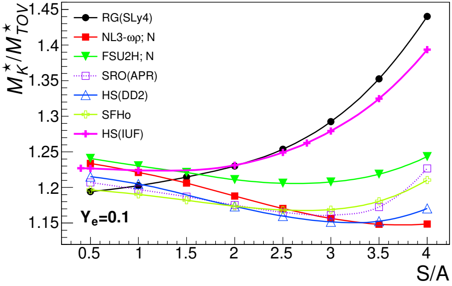
Including thermal effects in the merger remnant

Thermal effects potentially modify two points in the analysis

1. Baryon mass (A) conservation to estimate mass loss from ejection needs $A(M_K^\star)$ at collapse
2. Relating $M_K^\star$ to $M_{\mathrm{TOV}}^\star$ (no longer universal !)

- Calculations with LORENE library ; $S/A =$ const and $Y_e =$ const and a set of finite-temperature EoS
- Competing thermal effects :
  - extend the star (low S/A)
  - increase the supported mass (high S/A)

  $\rightarrow$ minimum in $M_K^\star/M_{\mathrm{TOV}}^\star(S/A)$



- Typical ranges for merger remnant $Y_e \approx 0.1$ and $2 \lesssim S/A \lesssim 3$ [Perego+ 2019]

l'Observatoire de Paris — LUTH — Laboratoire Univers et Théories

SUMMARY

We find from GW170817

UNIVERSAL LIMITS FOR HOT NON-ROTATING STARS

$$M^\star_S(\frac{S}{A} = 2, Y_e = 0.1) = 2.19^{+0.05}_{-0.03} M_\odot, \quad M^\star_S(\frac{S}{A} = 3, Y_e = 0.1) = 2.36^{+0.05}_{-0.04} M_\odot$$

and

LIMITS FOR TOV MASS (WITH $C^\star_M \approx 1.18$)

$$2.16^{+0.09}_{-0.07} M_\odot < M^\star_{\mathrm{TOV}} < 2.24^{+0.09}_{-0.07} M_\odot$$

Comments :

- Thermal effects relax previous limits, but attention, final value EoS dependent (our EoS set gives a range $1.15 \lesssim C^\star_M \lesssim 1.3$)
- Higher electron fraction $\rightarrow$ smaller $C^\star_M$ $\rightarrow$ limits further relaxed

l'Observatoire de Paris — LUTH
Laboratoire Univers et Théories