# Antikaon condensates with Dark vector meson in Neutron stars

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## Introduction

Neutron stars are alluring objects that serves as a natural laboratory to probe exotic states of dense matter. Recent observation of gravitational waves from compact star mergers such as **(GW170817, GW190814)** has opened a new window to the Universe and may possibly connect to the dark matter sector as well. Although various novel phases of matter such as hyperons, condensates, quarks etc. are energetically favourable in the dense core of compact stars and even dark matter may. Of the various possibilities, presence of antikaon condensates is known to render the EoS softer resulting in a smaller maximum mass for the neutron star than when it is not considered. In present investigation, we analyze the neutron star properties such as mass-radius and tidal deformability in presence of antikaon condensation ($K^-$) along with the presence of dark vector meson. For this we seek two fluid approach to analyze the NM + $K^-$ and DM equation of state and static neutron star properties.

## Results and Discussion

To account for the nuclear matter EOS, we employ the FSUH (nuclear) model, the details of which can be found in [1]. Similarly the procedure for inclusion of antikaons with baryons can be found in Ref.[2]. As per literature, the most accepted value of the $K^-$ optical potential lies in the range of 180 ± 20 MeV at saturation density. In the present work, we vary the optical potential in the range (-120 to -160) MeV.

In the mean field approach we consider fermionic dark matter, the interaction of which is mediated by 'dark vector boson'. The DM EoS is expressed as,

$$\epsilon_{DM} = \frac{1}{\pi^2}\int_0^{k_D} dk k^2 \sqrt{k^2 + (M_D)^2} + \frac{g_{\nu d}^2}{2m_{\nu d}^2}\rho_D^2 (1)$$

$$P_{DM} = \frac{1}{3\pi^2}\int_0^{k_D} dk \frac{k^2}{\sqrt{k^2 + (M_D)^2}} + \frac{g_{\nu d}^2}{2m_{\nu d}^2}\rho_D^2 (2)$$

Here $M_D$ is the mass of fermionic dark matter, $m_{vd}$ is the corresponding mass of the vector dark meson. Finally adopt two fluid formalism to study the properties of DANS (Dark matter admixtured Neutron stars).

For spherical symmetric static compact stars configuration we show our results of the mass-radius relation in Fig.1. The maximum mass and radius obtained with pure nuclear matter for FSU2H parametrization is 2.40 $M_\odot$ and 13.63 Km respectively. When we consider anti-kaons in addition to the nucelons they are reduced for all range of $U_k$, keeping the $R_{1.4}$ same. With the addition of DM, $R_{max}$ and $R_{1.4}$ decreases significantly where as the reduction in mass of NS happens after adding more than 10% of DM. Our results agree well with the bounds placed on a 1.4 $M_\odot$ NS from GW170817 by LIGO/Virgo except when the DM fraction is 30 percent for potential $U_k$=-160 MeV where mass at $R_{1.4}$ is 1.96 $M_\odot$

The dimensionless tidal deformability ($\Lambda$) is the measure of the degree of deformation of a neutron star due to the tidal field of the companion star. As tidal deformability scales with the radius, with decreasing radius $\Lambda$ decreases. In this work, we found that the tidal deformability for pure nuclear matter and the one

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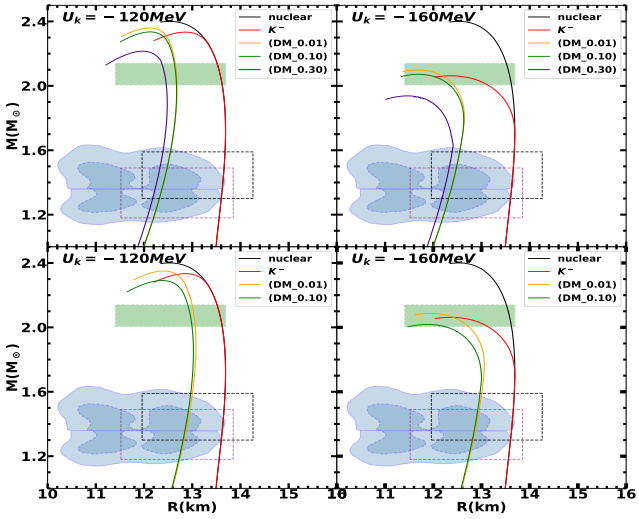


FIG. 1: The neutron star mass-radius plotted (Top) plots are with DM mass 1 GeV where left panel is with $U_k$=-120 and right panel is with $U_k$=-160. Similarly the bottom plots are with DM mass 0.5 GeV. Black solid line is nuclear matter, red solid line is nuclear matter with antikaons and other solid lines are various fractions of DM mixed with nuclear matter and $K^-$. The rectangular regions enclosed by dotted lines indicate the constraints from the millisecond pulsar PSR J0030+0451 (black & puprple) NICER x-ray data and PSR J0740+6620 (green)

with antikoaons do not agree with the range obtained from GW170817 data analysis ($\Lambda_{1.4}$ from GW170817 is $190^{390}_{-120}$ at 90% confidence level). While adding antikaons with NM there is no change in $\Lambda_{1.4}$, which is 779 obtained for both. When we start adding DM, $\Lambda_{1.4}$ decreases significantly and agrees well with GW170817 data.

## Conclusions

We investigated the role of antikaon condensation and its effect with dark vector meson in static neutron stars. The presence of $K^-$ results in smaller maximum mass for the stars and independent of the Kaon potential depth. It is rather interesting to note that with the addition of dark matter, we see significant decrease in the radius and its tidal deformability, both of which now agrees to the range specified by GW170817 data.

## References

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