Summary and Conclusion

In this thesis, we have investigated the behaviour of matter at very high density using a relativistic Lagrangian description. The Lagrangian chosen by us corresponds to the chiral sigma model. This approach is considered to be a "good" low energy limit of quantum chromo dynamics. Although there have been a few previous calculations along this line, a detailed and consistent field theoretical approach has been lacking. The calculations presented in this thesis are aimed at such a detailed study. We have extended these calculations for the case of finite temperatures (≤ 15 MeV). The results are expected to find application in stellar collapse calculations. In addition, we have dealt with the following subjects: (1) Phase transition to quark matter and the possible formation of strangelets at high densities and (2) astrophysical applications of our results, to (a) structure and radial oscillation of nonrotating neutron stars and (b) the neutrino emissivity of quark matter with an improved calculation of phase space integrals involved.

The highlights and main results of this thesis can be summarized as follows:

1. The energy per nucleon of cold nuclear matter (kB T = 0), derived by us using chiral sigma model, is in good agreement with the preliminary estimates inferred
from heavy-ion collision data [57] in the density range between one to four times
the nuclear saturation density ($n_s$).

2. For a system of high density nuclear matter, based on the chiral sigma model, we find
that a strict first order phase transition to ($u$, $d$, $s$) quark matter is not favoured.
This does not, of course, preclude a phase transition of second order. However, we
have not investigated the latter problem.

3. The mass formulae for finite lumps of strange quark matter with $u$, $d$ and $s$ quarks
and non-strange quark matter ($u$ and $d$) are derived in a non-relativistic approach,
taking into account the finite size effects such as surface and curvature. We find
that there is a good possibility for the formation of metastable strangelets of large
mass detectable in experiment. This is important since the detection of strangelets
may be the most unambiguous way to confirm the formation of quark-gluon plasma
in heavy ion collision experiment.

4. The maximum mass for stable neutron stars predicted by our equation of state
for ($n$, $p$, $e$) matter is 2.59 times the solar mass. The corresponding radius ($R$),
crustal length ($\Delta$) and surface red shift ratio ($\alpha$) are 14.03 km, 1.0 km and 0.674
respectively. The maximum moment of inertia is $4.79 \times 10^{45} g cm^2$. These suggest
that our equation of state for neutron star matter is comparatively "stiff". This is
reflected in the value of the maximum mass of neutron stars, which is the largest for
the present model as compared to other available field theoretical equation of state
models. It may be mentioned here that observational evidence in favour of a stiff
equation of state comes from the identification by Trümper et al. [64] of the 35 day
cycle of the pulsating X-ray source Her X-1 as originating in free precession of the rotating neutron star (Pines [65] for a discussion). For a 1.4 times the solar mass neutron star configuration, we get: \( R = 14.77 \text{ km} \), \( I = 2.15 \times 10^{45} \text{ g cm}^2 \), \( \Delta = 3.0 \) km and the red shift ratio (at the surface) \( \alpha = 0.85 \). The corresponding central density is \( 4.06 \times 10^{14} \text{ g cm}^{-3} \).

5. The neutrino emissivity from two and three flavour quark matter is numerically calculated and compared with the result given by Iwamoto [149]. We find that the emissivity is smaller than Iwamoto's result by about two orders of magnitude when \( p_f(u) + p_f(e) - p_f(d(s)) \) is comparable to the temperature. We attribute this to the severe restriction imposed by momentum conservation on the phase space integral. An alternative formula for the neutrino emissivity, which is valid when the quarks and electrons are degenerate and any values of \( p_f(u) + p_f(e) - p_f(d(s)) \) is obtained by us.