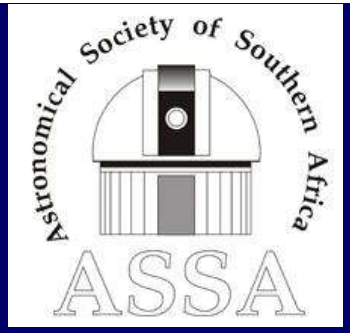
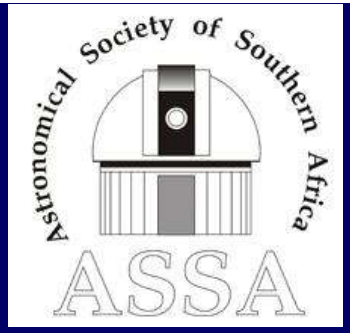


A Comparative Study of Quark-Gluon Plasma at the Core of a Neutron Star and in the Very Early Universe

By

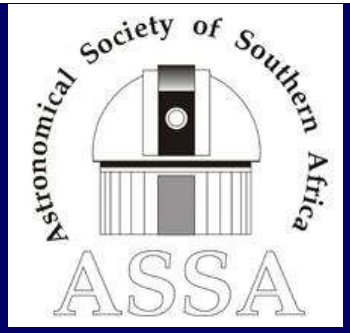
Frikkie de Bruyn



Introduction

1 Study of quark-gluon plasma fluid is of mutual Interest to both astrophysicists and cosmologists

2 Good example in the case of astrophysics is the quest to understand the composition of neutron stars

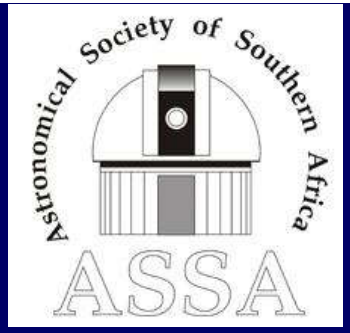


1 Nuclear physics explains how a neutron star forms:

$$e + p - n + v$$

2 Quarks are normally confined to hadrons and mesons held together by the carriers of the strong nuclear force, gluons.

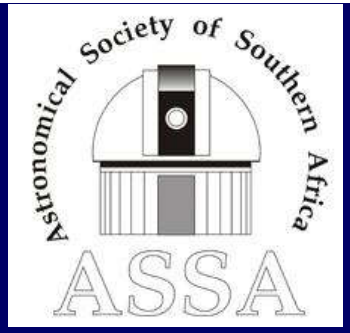
3 Interesting question of having quarks in deconfined state together with gluons in the cores of neutron stars.



1 Quark-gluon plasma (QGP) almost certainly existed in the early universe

2 The extreme conditions in the early Universe and compact stellar objects are transiently recreated in the LHC in Switzerland and in particle colliders in the USA

3 The creation of quark-gluon plasma in these experiments will tell cosmologists a great deal about conditions in the early Universe.



What is a quark-gluon plasma?

1. QGP is a phase transition of Quantum Chromodynamics (QCD) which exists at very high temperatures and/or density.

2. Normal matter each quark pairs with an anti-quark to form a meson or with two other quarks to form a baryon

3. In QGP by contrast, these mesons and baryons lose their identities to dissolve into plasma of quarks and gluons

1 The force between quarks approaches a constant strength if you move the quarks apart.

2 However when quarks are very close together the force between them weakens.

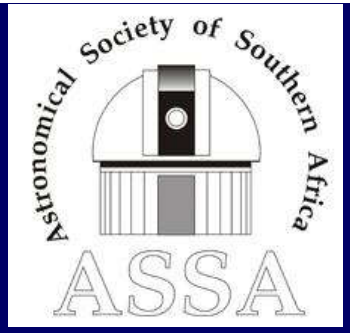
3 This could explain why quarks are released in asymptotic freedom at the core of a strange star.

How is QGP created?

1. In the LHC near Geneva by accellerating protons at ultra relativistic speeds to 99.9975 percent of the speed of light & let them collide at 30 million times a second for up to 10 hours

2. The resulting fireball is of a transient nature.

3. The existence of QGP is inferred from the fall out of particles created in the fireball.



QGP in Stars

1 Using two NASA satellites, the Rossi X-Ray Timing Explorer and the Chandra X-Ray Observatory the interiors of a group of radio quiet neutron stars are probed

2 Insight is gained into the interiors through events called glitches

3 The star PSR J0537-6910 is dubbed the big Glitcher.

4. A glitch is a sudden change in the precision spin of the star. Glitches speed up the spin of the neutron star.

1 Theory is that the spin of the star's I km thick crust of solid iron is slowed by the magnetic field.

2 The quark-gluon plasma in interior speeds up the spin.

3 The difference between the two speeds reaches a critical stage and suddenly transfers its built-up angular momentum to the exterior to spin faster

4 The size of the glitch can be measured in terms of how much faster the star spins.

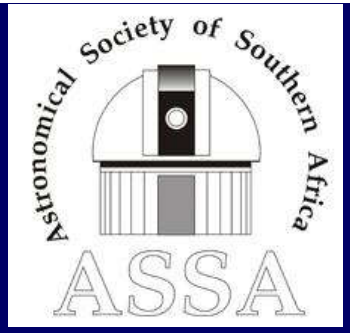
5. Quarks may escape through the crack in the star's exterior to form a meson.

1 Quarks have less energy than neutrons and an enormous amount of energy may escape when quarks are deconfined.

2 This might explain some of gamma ray bursts (GRB's).

3 To understand the star's interior astrophysicists need to know the ratio between the star's mass and radius.

4 Masses are well known, particularly in binary systems in which the orbital period is determined by the mass and the radius.



1 Using the Chandra X-Ray Observatory two more candidates have been identified on 10 April 2002.

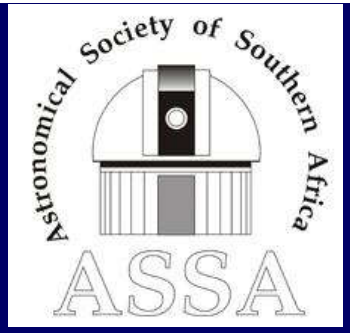
2 RX J 1856-5.3754 and 368 are much smaller than canonical neutron stars and much colder than neutron degeneracy matter.

3 Recently a third star, XJE J 1739.285 was identified as a possible candidate.

4 Observations of supernovae SN 2006gy and SN 2005ap point to the existence of quark stars.

5 A quark star is the intermediate stage between a canonical neutron star and a black hole, both in terms of mass and density.

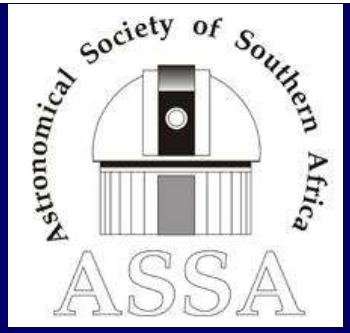
6 The best candidates are radio quiet stars with rapid spin and masses between 1.5 and 1.8 solar masses.



QGP in the early Universe.

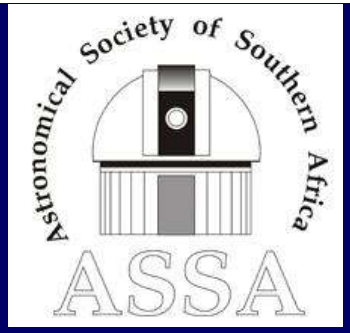
1 QGP was almost certainly present in the early Universe

2 In the early UniverseQGP preceded the hadronic phase while in a strange star the opposite happens.



3 The temperatures and densities created in the LHC near Geneva interpolated between extreme conditions of the very early Universe and compact stellar objects such as strange stars.

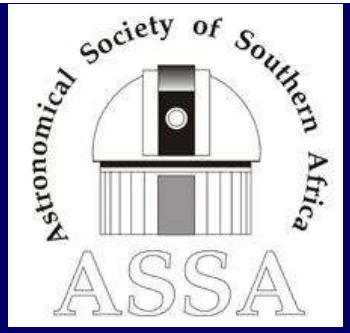
4 Data gathered during experiments at the LHC at CERN indicated that QGP should be created at temperatures of 1 TeV.



Conclusions

1 In this paper I have presented the current research into the contents of a group of radio quiet neutron stars and the possibility that quarks and gluons may exist in deconfined state.

2 Astrophysicists and cosmologists are currently investigating the existence of quark-gluon plasma in strange stars and in the early Universe.



3 **Results from particle accelerators point to the existence of this exotic form of matter.**

THANK YOU