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COMPACT STARS IN  
THE STANDARD MODEL  
- AND BEYOND

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# TRADITIONAL COMPACT OBJECTS

## → WHITE DWARF STARS

FERMI PRESSURE OF ELECTRONS

$$M < 1.4 M_{\odot} \quad R \sim R_{\text{EARTH}} \quad \rho < 10^8 \text{ g/cm}^3$$

//////////////////// DESERT OF INSTABILITY //////////////////////////////////////

## → "NEUTRON STARS"

FERMI PRESSURE OF NUCLEONS/  
HYPERONS/  
QUARKS...

$$M < 2-3 M_{\odot} \quad R \sim 10 \text{ km} \quad \rho < 10^{16} \text{ g/cm}^3$$

//////////////////// DESERT OF INSTABILITY //////////////////////////////////////

## → BLACK HOLES

THE OBJECT COLLAPSES INDEFINITELY,

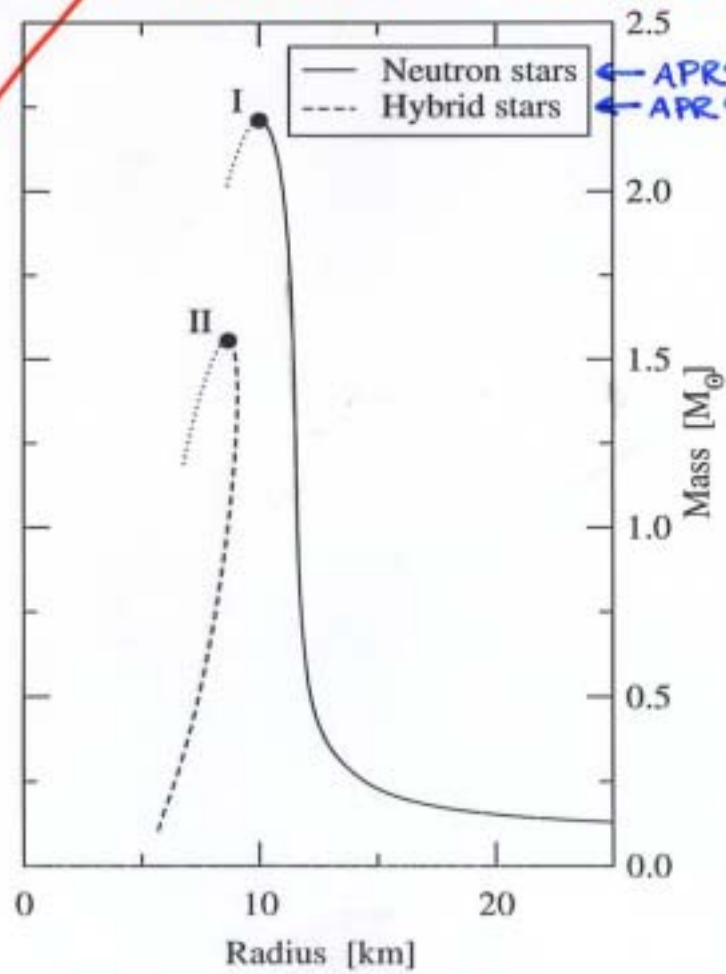
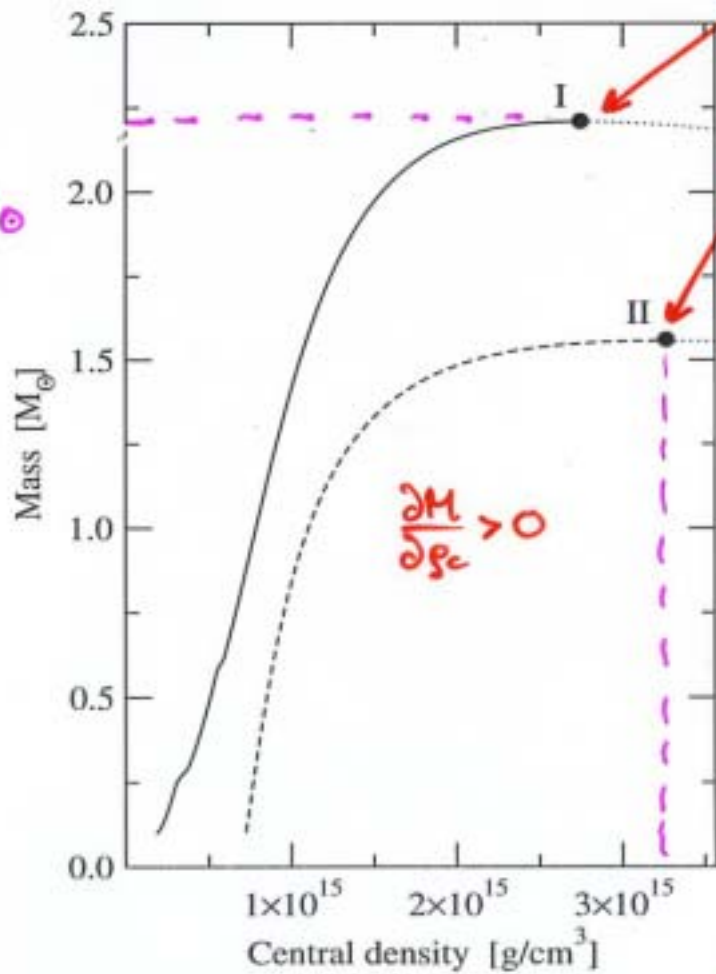
OR TO THE PLANCK SCALE  $\rho \sim 10^{93} \text{ g/cm}^3$

# GENERAL RELATIVISTIC EQUILIBRIUM CONFIGURATIONS (OV SOLUTIONS)

Ex.

MAXIMUM MASS CONFIGURATIONS  
STABILITY  $\rightarrow$  INSTABILITY !

$M \sim 2 M_{\odot}$



$\rho < 10^{16} \text{ g/cm}^3$

$R \sim 10 \text{ km}$

— EOS AT NEUTRON STAR DENSITIES

UNKNOWN, BUT :

$M_{\text{MAX}} \sim$  A FEW SOLAR MASSES

$R \sim 10$  km

$\rho < 10^{16}$  g/cm<sup>3</sup> |

FOR ANY STAR  
COMPOSED OF  
QUARKS AND  
LEPTONS !

SINCE:

$\mu < m_c$  (+ ASYMPTOTIC FREEDOM)

⇒ ONLY u d s QUARKS IN

STABLE STARS ⇒ ...

(KETTNER et al., PHYS. REV. D51, 45)

THERE IS NO PARTICLE (FERMION)

THAT CAN STABILISE A MORE

DENSE CLASS OF STARS.



THAT IS ...

x IF QUARKS AND

LEPTONS ARE FUNDAMENTAL

PARTICLES.

x WHICH IS NOT NECESSARILY  
THE CASE.

(ORIGIN OF FAMILIES, MIXING, OSCILLATIONS...)

EX. "PREON TRINITY" MODEL

J.-J DUGNE et al., EUROPHYS. LETT. 57 (2002).

PREON SCHEME

CHARGE	+e/3	-2e/3	+e/3
SPIN 1/2	$\alpha$	$\beta$	$\delta$
SPIN 0	$(\bar{\beta}\bar{\delta})$	$(\bar{\alpha}\bar{\delta})$	$(\bar{\alpha}\bar{\beta})$

COMPOSITE STATES

	$\beta\delta$	$\alpha\delta$	$\alpha\beta$	$\bar{\beta}\bar{\delta}$	$\alpha\bar{\delta}$	$\alpha\bar{\beta}$	$\bar{\alpha}$	$\bar{\beta}$	$\bar{\delta}$
$\alpha$	$\gamma_e$	$\mu^+$	$\gamma_\tau$	$u$	$s$	$c$	$Z^0/Z'$	$W^+$	$Z^*$
$\beta$	$e^-$	$\bar{\nu}_\mu$	$t^-$	$d$	$x$	$b$	$W^-$	$Z'/Z^0$	$W'^-$
$\delta$	$\gamma_{x1}$	$K^+$	$\gamma_{x2}$	$h$	$k$	$t$	$\bar{Z}^*$	$W'^+$	$Z''/Z'$

LEPTONS
QUARKS
VECTOR BOSONS

SEE: S. FREDRIKSSON, IN "BEYOND THE DESERT 2003",  
 hep-ph / 0211335.

A SIMPLE ESTIMATE OF THE  
MASS AND RADIUS OF A NEUTRON  
STAR.

$$R \sim 2GM / c^2$$

$$M \sim mA$$

$$R \sim d_0 A^{1/3}$$

NUCLEON



$$m \sim 939 \text{ MeV}/c^2$$



$$d_0 \sim 0.5 \text{ fm}$$



$$\begin{aligned} R &\sim 7 \text{ km} \\ M &\sim 2.5 M_{\odot} \\ \bar{\rho} &\sim 10^{15} \text{ g/cm}^3 \end{aligned}$$

... AND FOR A "PREON" STAR

$$R \sim 2GM / c^2$$

$$M \sim mA$$

$$R \sim d_0 A^{1/3}$$

COMPOSITE ELECTRON



$$m = 511 \text{ keV} / c^2$$



$$d_0 \lesssim \hbar c / \text{TeV} \sim 10^{-19} \text{ m}$$



$$M < 10^2 M_{\oplus} \sim 10^{27} \text{ kg}$$

$$R < 1 \text{ m}$$

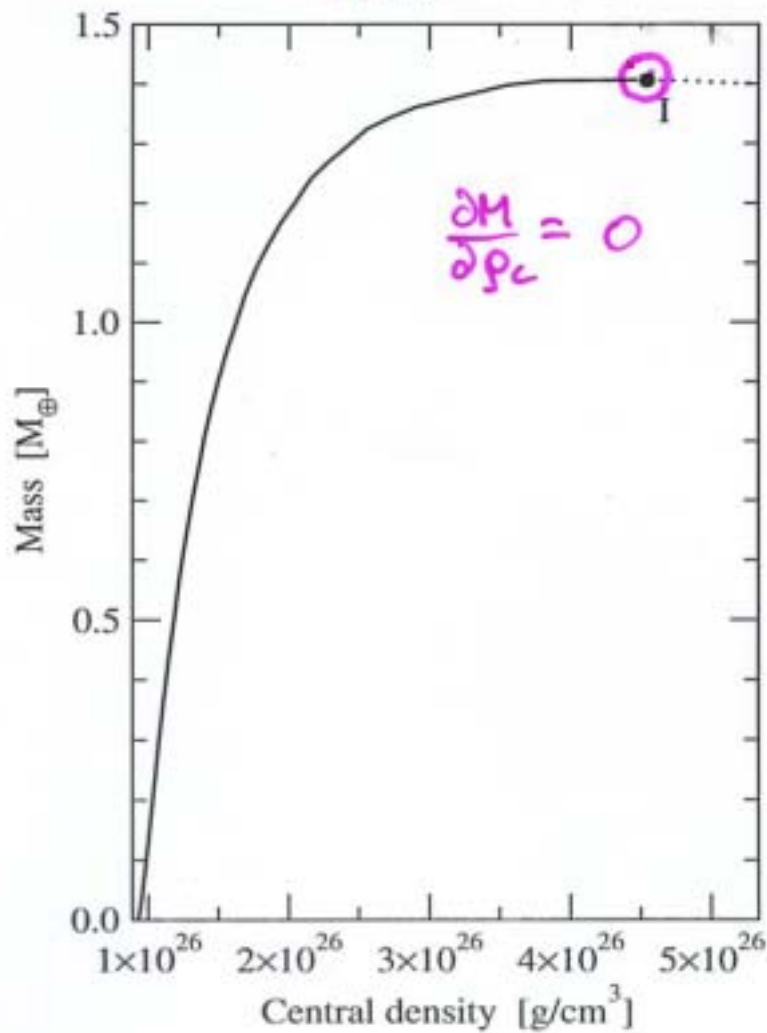
$$\bar{\rho} > 10^{23} \text{ g/cm}^3$$



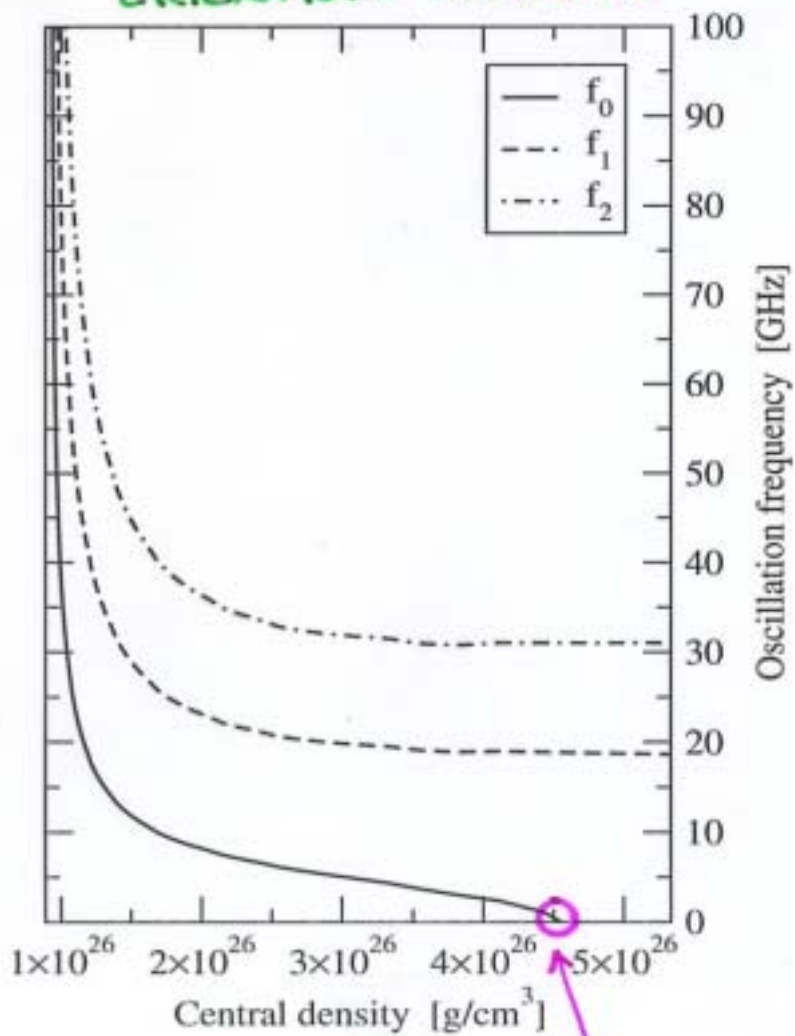


$$B^{1/4} = 100 \text{ GeV}$$

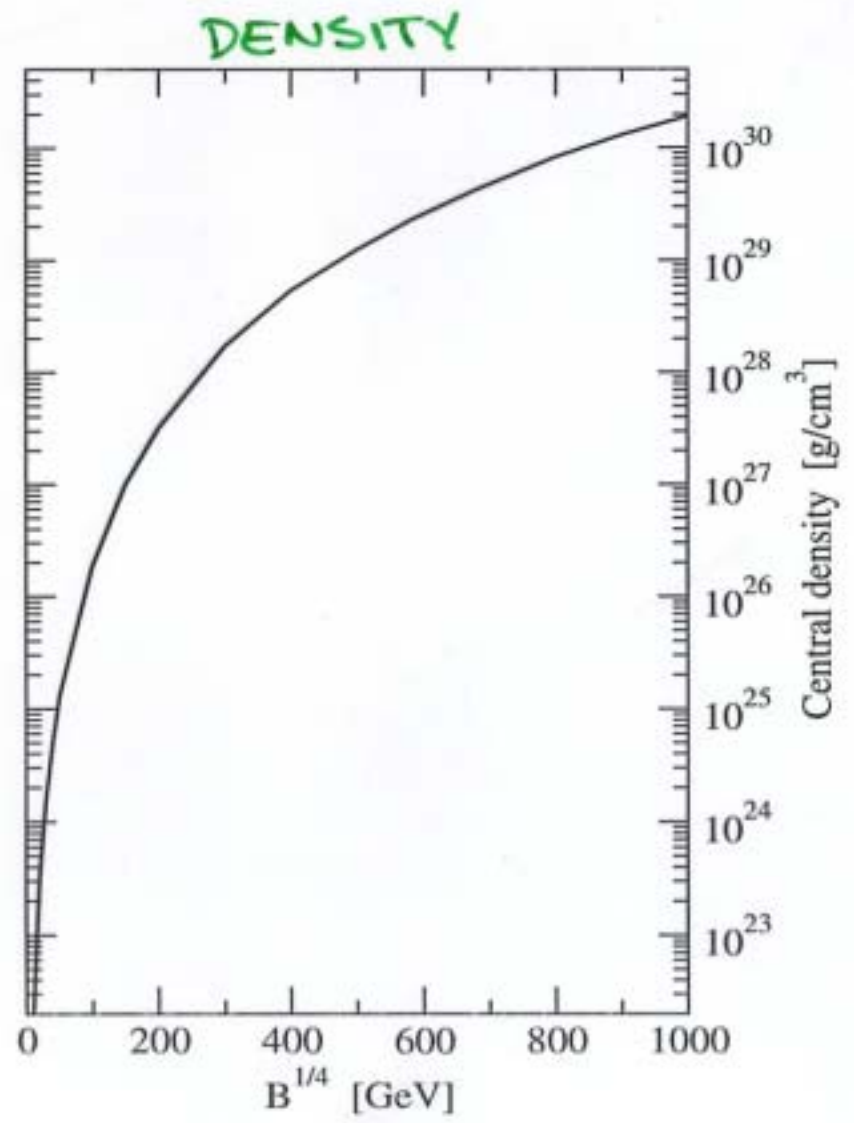
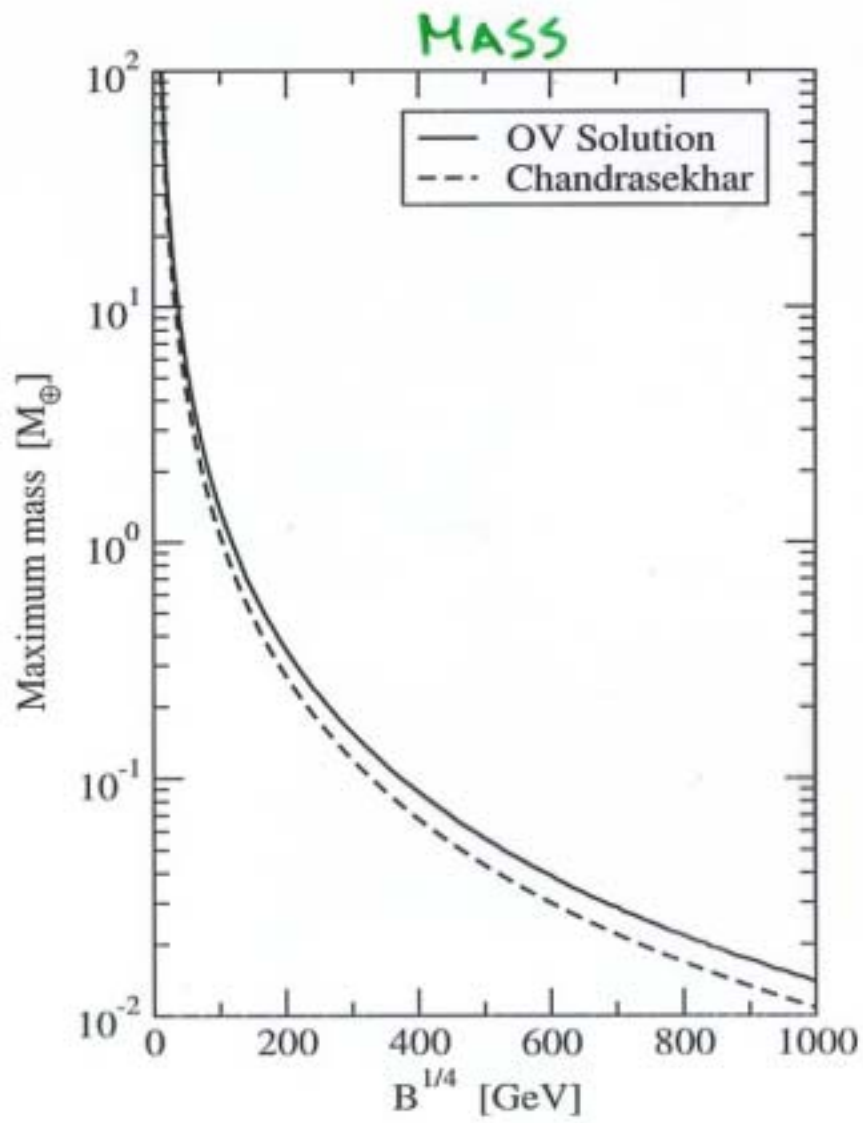
MASS

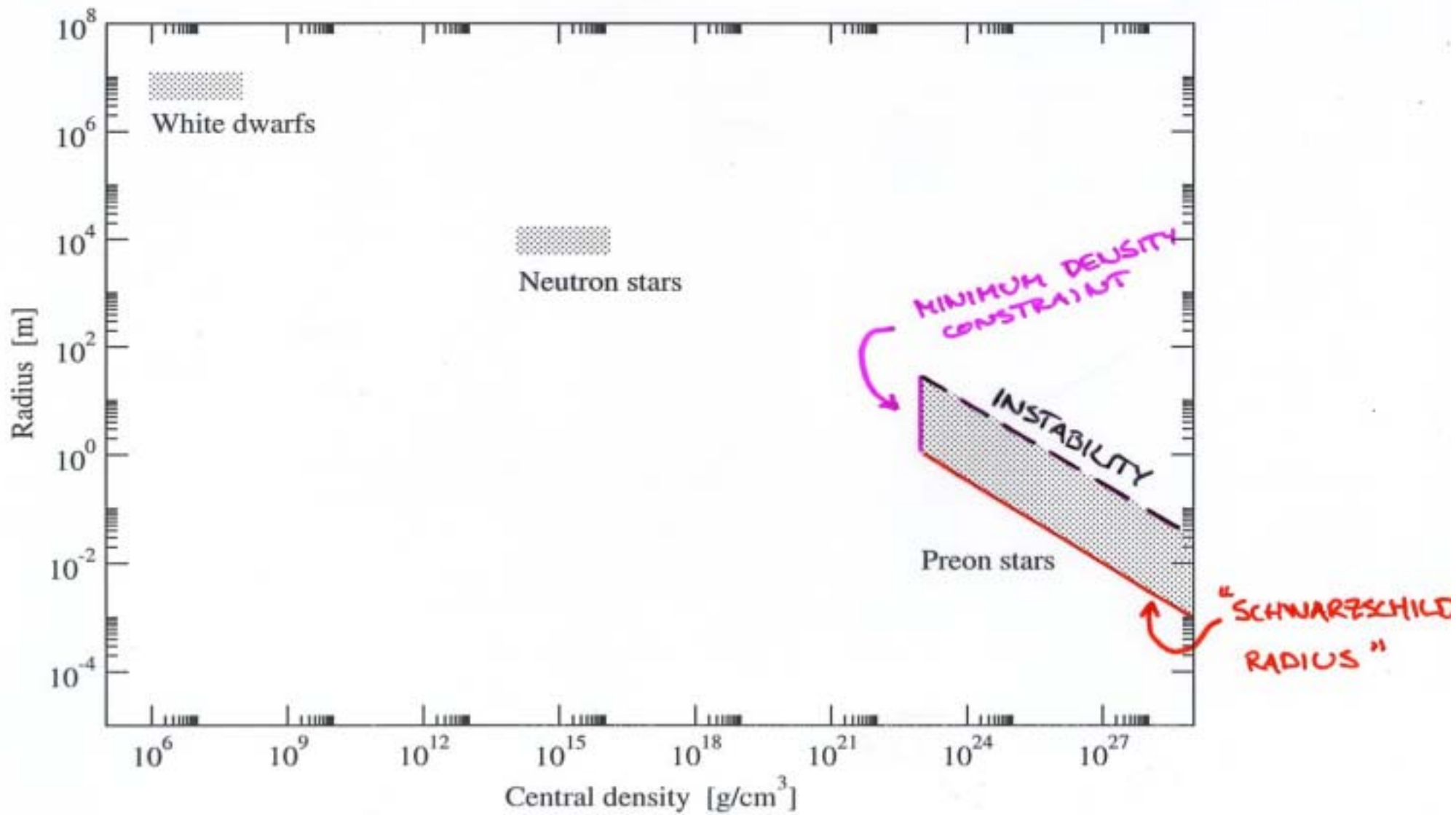


GENERAL RELATIVISTIC  
EIGENMODE ANALYSIS



STABLE  $\rightarrow$  INSTABLE





$$\Omega_{DM} \sim 0.2$$

OBSERVATIONAL CLUES

ARE NEEDED.



# PICO- AND FEMTOLENSING



MULTIPLE IMAGES  $\Rightarrow$  INTERFERENCE

$$10^{-16} M_{\odot} \lesssim M \lesssim 10^{-11} M_{\odot}$$

FEMTOLENSING

$$\lesssim M \lesssim 10^{-7} M_{\odot}$$

PICOLENSING

GOULD A., ApJ, 1992

STANEK K.Z. et al., ApJ, 1993

ULMER A. ...

X LENSING ONLY REASONABLE IF PREON STARS ARE ABUNDANT ENOUGH

$$\Omega_{PS} \sim 0.1$$

X ONLY REASONABLE IF THEY FORMED IN THE EARLY UNIVERSE

AT  $T = 1 \text{ TeV}$ :

$$\left( \text{JEANS LENGTH} \right)$$
$$\lambda_J \sim H^{-1}$$




$$H^{-1} \sim 1 \text{ mm}$$

X HENCE, PS HAVE MASSES IN THE CORRECT INTERVAL FOR PICOLENSING (OR FEMTOLEN.)

$$10^{-1} M_{\oplus} \sim 10^{-7} M_{\odot}$$

# SUMMARY

- x IF THERE IS A DEEPER LAYER OF FERMIONIC CONSTITUENTS, BELOW THAT OF QUARKS AND LEPTONS, A NEW CLASS OF COMPACT STARS COULD EXIST.
- x OBSERVATIONAL CLUES ABOUT DARK MATTER ARE NEEDED.
- x BY LOOKING FOR GRAVITATIONAL LENSING OF GRB, SUCH CLUES MIGHT BE OBTAINED.  
(AXON MINICLUSTERS, QUARK NUGGETS, ...)
- x IF (SMALL) OBJECTS WITH VERY HIGH DENSITIES,  $\rho \gg 10^{16} \text{ g/cm}^3$ , ARE FOUND.  

- x NEW STATE OF MATTER
- x INFORMATION ABOUT EOS AND SCALE