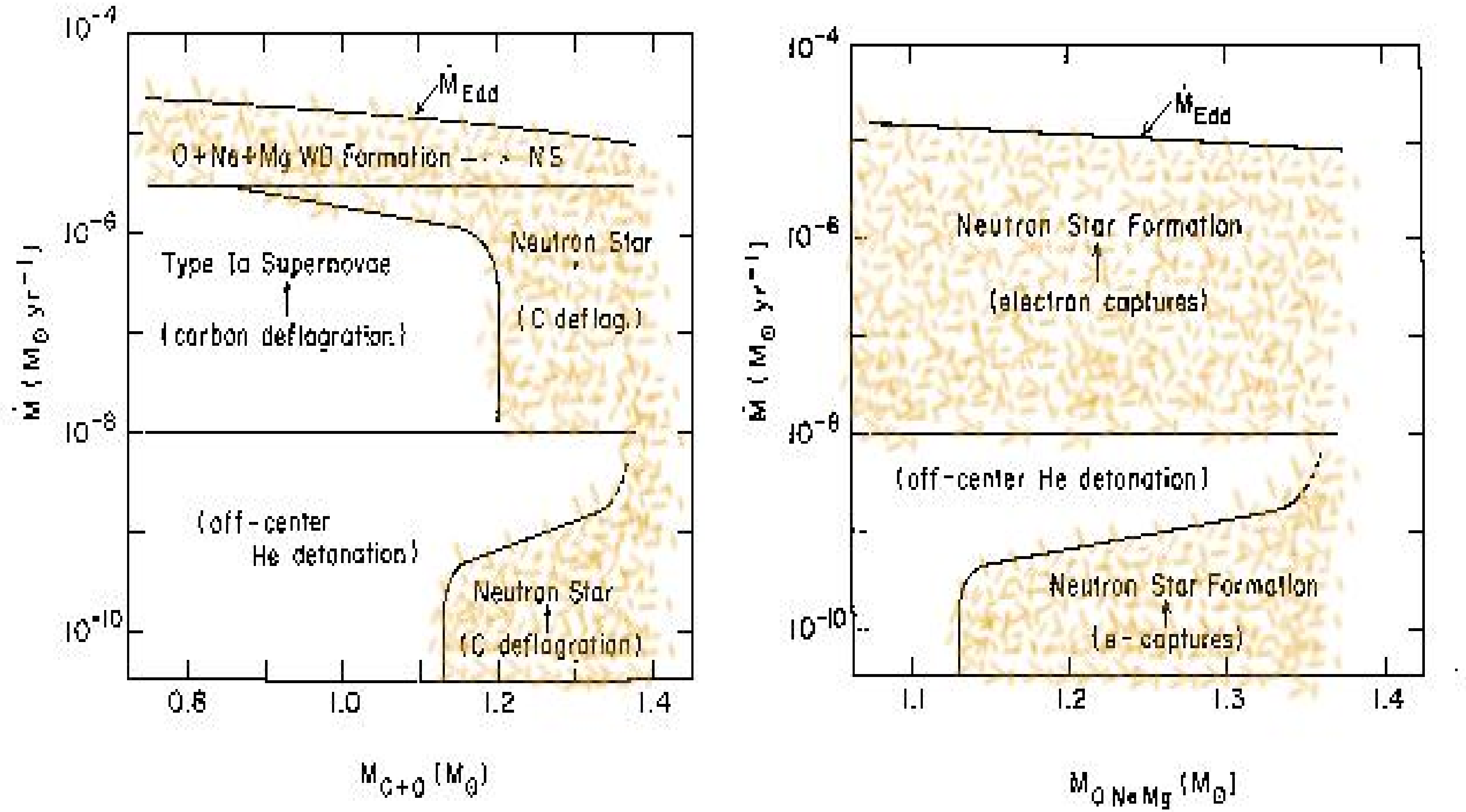
Gravitational Waves from Accretion Induced Collapse of White Dwarfs

Lee Lindblom and Yuk Tung Liu
Theoretical Astrophysics — Caltech

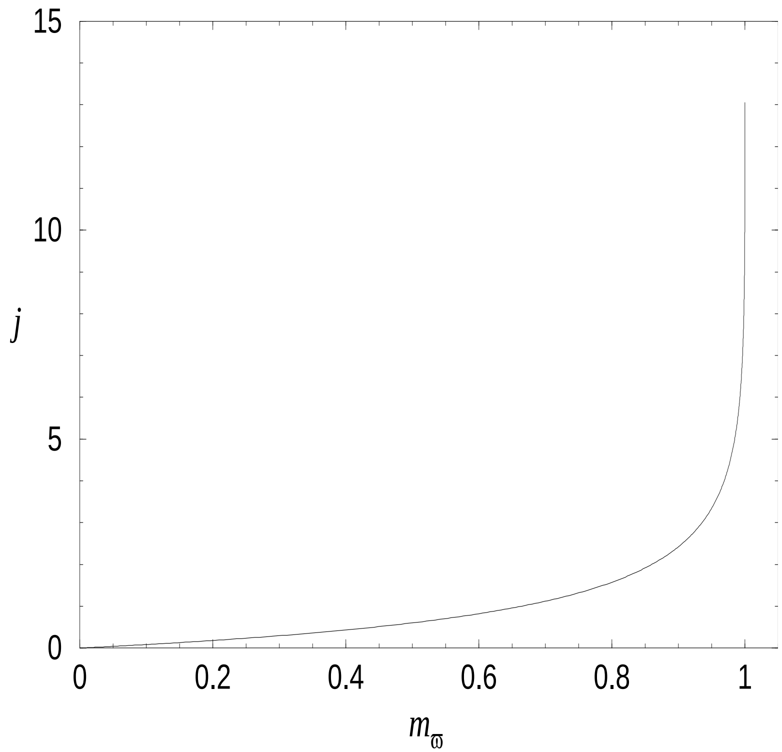
- Rapidly rotating neutron stars formed in the accretion induced collapse of a white dwarf may have dynamical instabilities which could emit detectable amounts of gravitational radiation with frequencies near 450 Hz.
- Only the most rapidly rotating O+Ne+Mg WDs collapse to NS with large enough $\beta = T/|W| > 0.24$ to have dynamical instabilities.
- The maximum optimal signal-to-noise ratio for detecting these events:

$$\frac{S}{N} = 15\left(\frac{20\mathrm{Mpc}}{D}\right)\sqrt{\frac{\Delta J}{5\times 10^{48}\mathrm{cgs}}}\sqrt{\frac{450\mathrm{Hz}}{f}}\left(\frac{2\times 10^{-24}\mathrm{Hz}^{-1/2}}{\sqrt{S_h(f)}}\right)$$

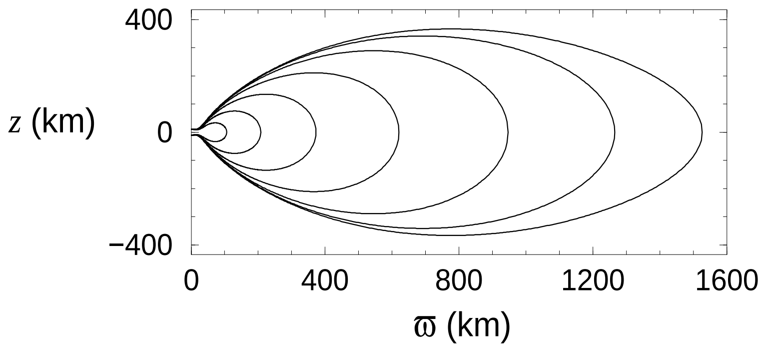
- Neutron Stars result from AIC if the density exceeds a critical value when nuclear transitions are triggered in the core (Nomoto & Kondo 1991). This critical density depends on the composition of the White Dwarf:

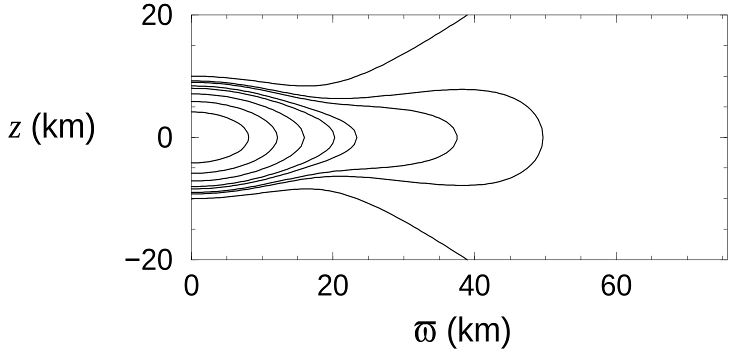


- Determine the angular momentum distribution $j(m)$ for rigidly rotating white dwarfs with central densities equal to the critical AIC values.

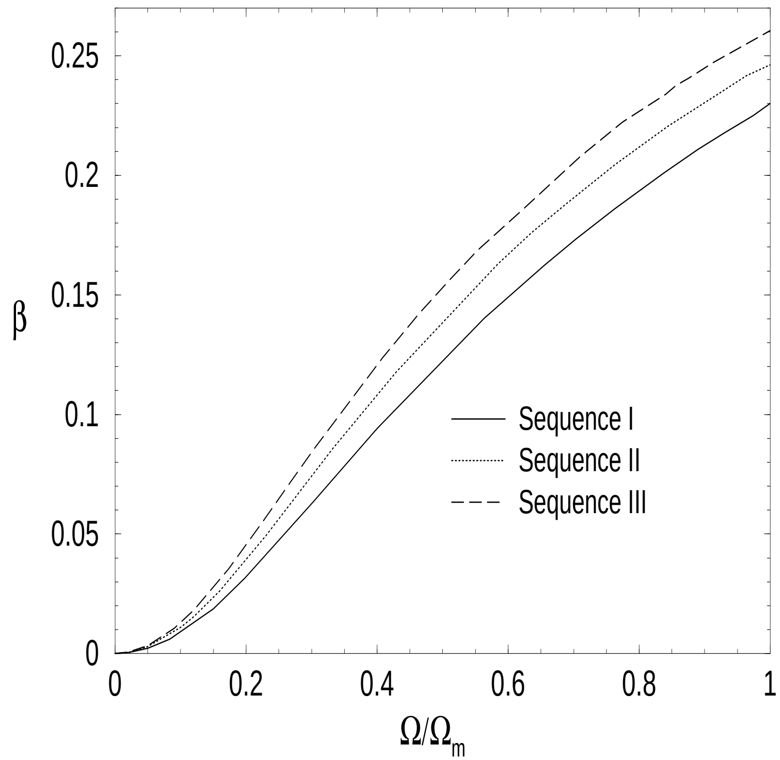


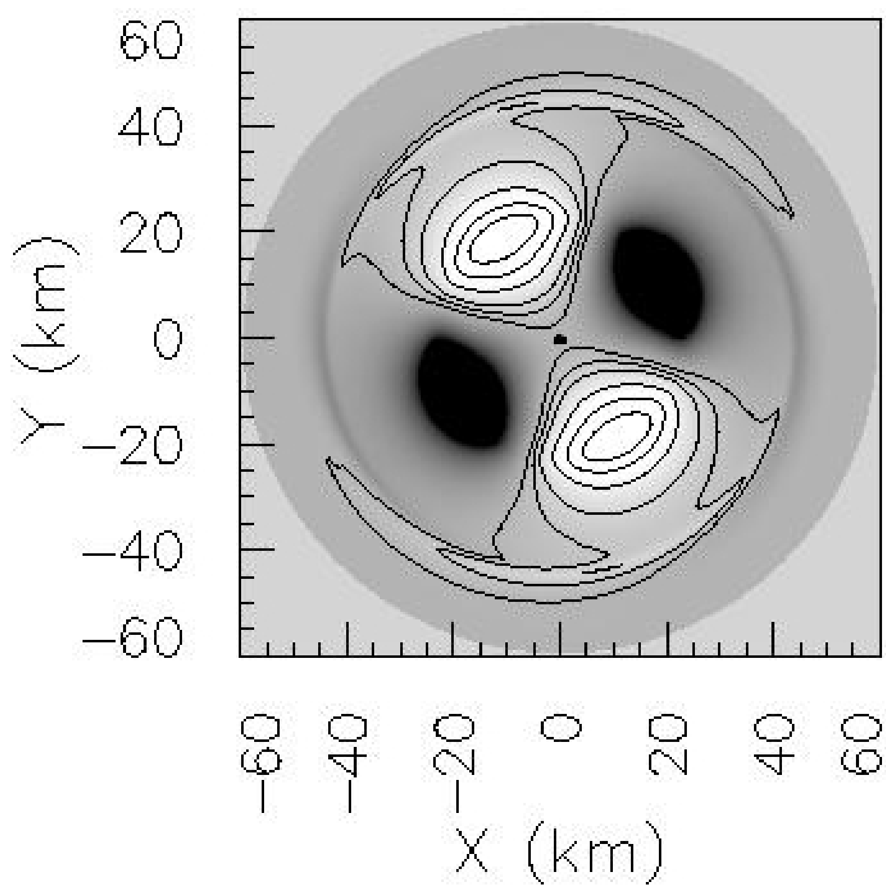
- Compute stellar models having the WD angular momentum distributions but realistic NS equations of state.





- $\beta = T/|W|$ as a function of the initial WD angular velocity Ω for two C+O sequences (solid curves) and one O+Ne+Mg (dashed curve), based on a realistic (cold) NS equation-of-state.
- Linearized numerical evolutions find dynamical instabilities in the $m = 2$ "bar" modes, but only for models with $\beta > 0.24$. Thus only the most rapidly rotating O+Ne+Mg WDs are subject to this instability.





- The maximum optimal $S/N \approx 15$ (for an event at 20 Mpc) is based on the assumption that a maximum angular momentum model $\beta = \beta_{\rm max}$ spins down by GR emission until dynamical stability is regained at $\beta = 0.24$.
- The timescale for the GR emission can be estimated from

$$\tau_{GR} \approx \Delta J \left(\frac{dJ}{dt}\right)^{-1} \approx 7{\rm s}\left(\frac{\alpha_S}{0.1}\right)^{-2}\left(\frac{\Delta J}{5 \times 10^{48}{\rm cgs}}\right)$$

where α_S is the dimensionless amplitude of the mode when saturation occurs, and ΔJ is the total amount of angular momentum radiated.

- Observation of this type of source by LIGO II seems unlikely unless the event rate exceeds 10^{-6}/galaxy/year.
- No dynamical instability is found in any model constructed from a realistic (hot) NS equation-of-state. The NS must cool before dynamical instability can play any role.
- No dynamical instability is found in any mode with $m \neq 2$.