So What Happens When We Detect GWs from CBCs?

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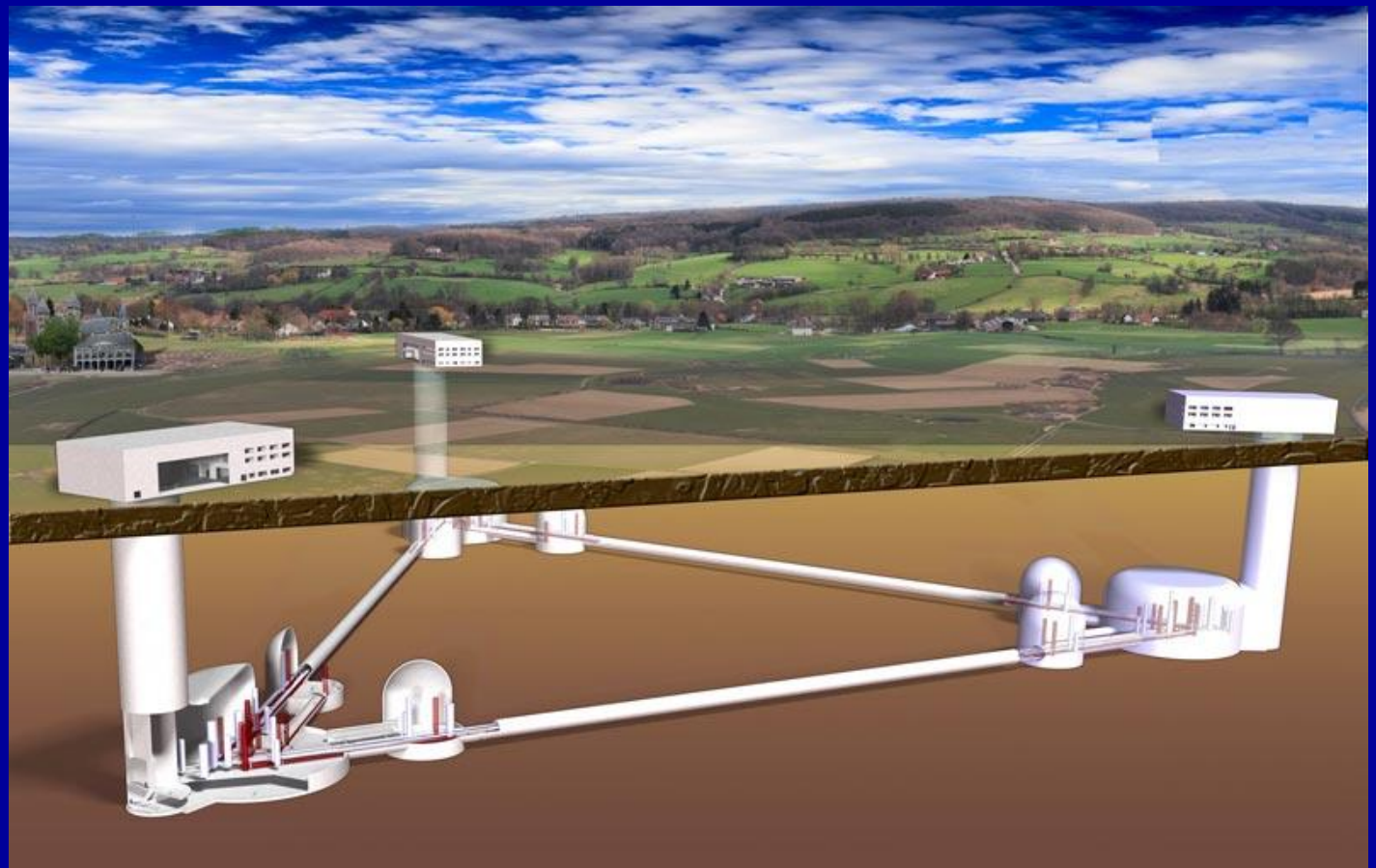


Outline

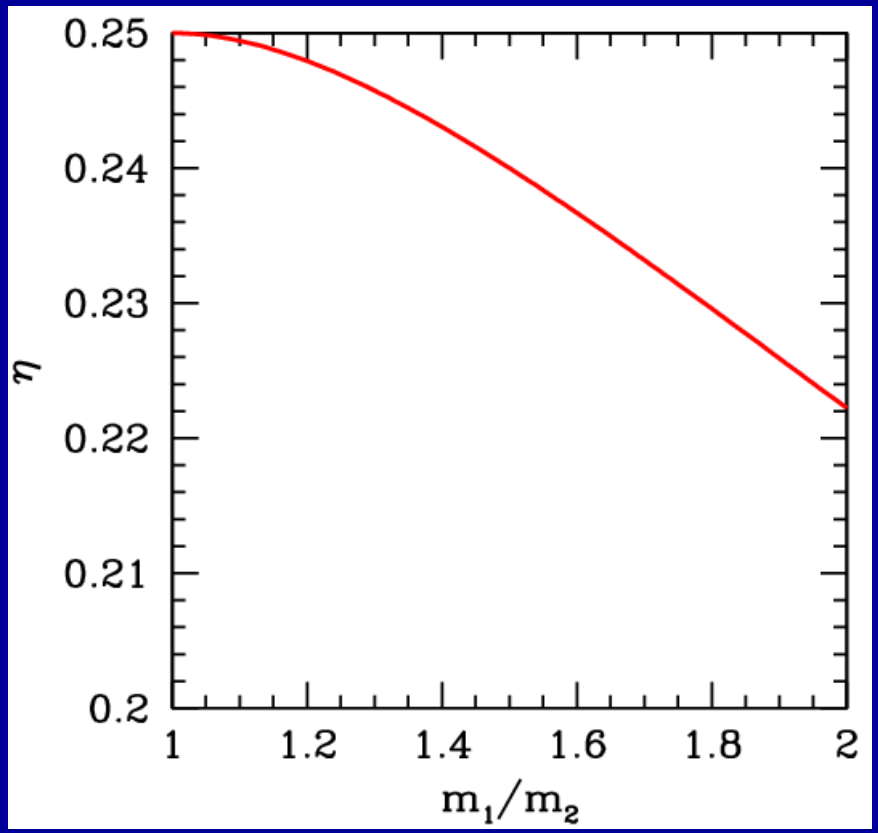
- What can we learn from early detections? How much does this depend on rates?
- For gen 2.5: low or high frequencies?
- What are data analysis requirements?
- Interpretation: nuclear physics
- Interpretation: binary evolution, dynamics Will we learn more from extraordinary events or from ordinary events?

Info from the First Detections

- Distinction: first GW detections, versus first GW+EM detections
- Focus on pure GW detections first
- How well can we get masses or other quantities in a CBC?

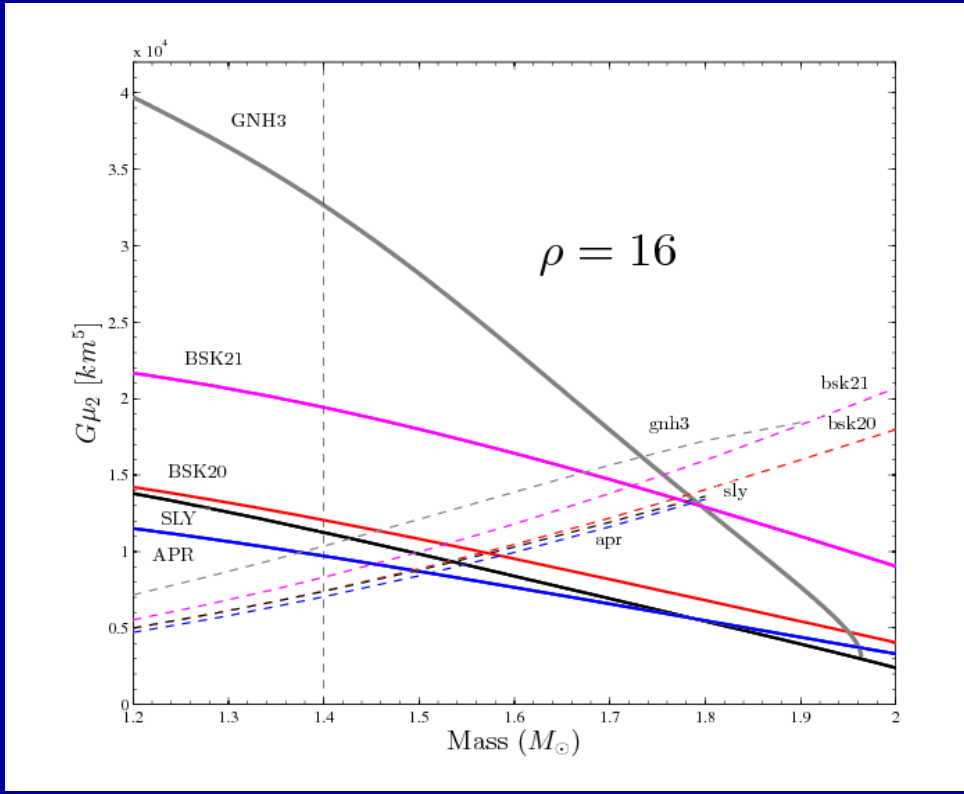
NS and BH masses

- Chirp mass is easy: $df/dt \sim \eta M^{5/3} f^{11/3}$
- Getting both masses requires symmetric mass ratio $\eta = m_1 m_2 / M^2$
- Need higher-order, high freq effects in GW
- Median $\Delta\eta \sim 0.015$ Veitch talk
- Bad for NS-NS; okay for NS-BH, maybe BH-BH(?)
- Low-mass BH vs. NS?
- Precision requirements depend on source



Neutron Star Radii

- NS tidal deviations from point mass
- Constraints scale as ρ^{-2}, number of events as ρ^{-3}, so low S/N events will provide most of the constraints (Markakis et al.; but see later). Premium on understanding noise!
- Caveats from Read talk, Favata poster



Damour et al., arXiv:1203.4352
Follows work by Read et al., Hinderer et al.

Constraints on Binary Models?

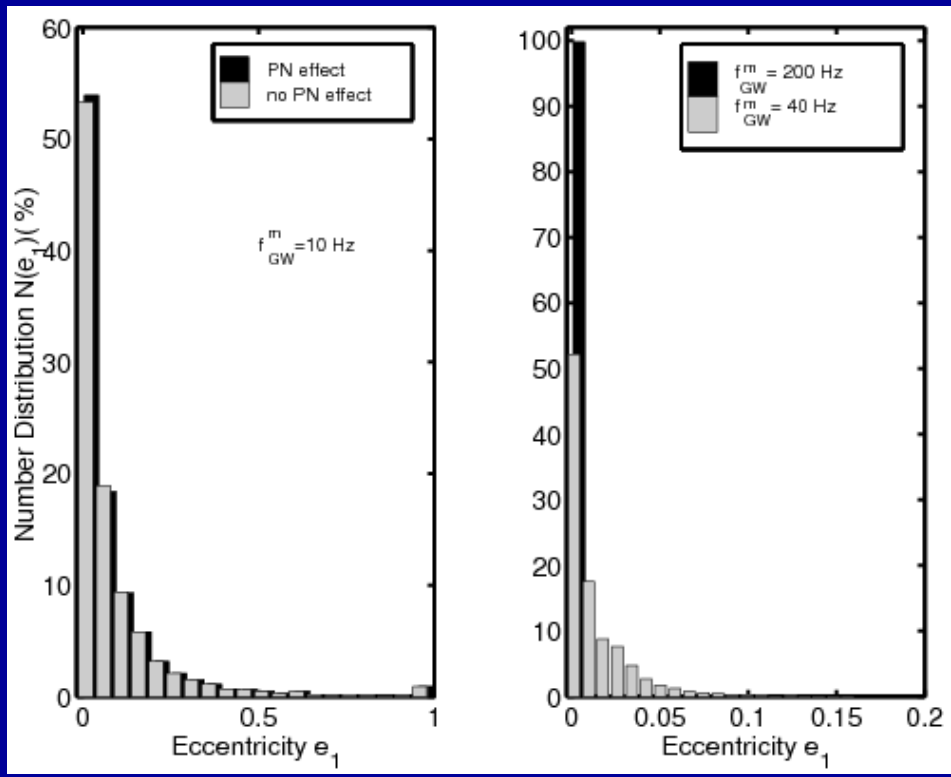
- My opinion: binary population synthesis models have more free parameters than the number of BNS sources, so it is unclear what they add to rates etc.
- How many CBC must be seen to overdetermine pop. synth. models?
  10? 30? 100?
- Necessary to get out more than we put in!

GW+EM Detections

- Various possibilities (e.g., ISS-Lobster; Gehrels talk, Camp poster)
- What if short hard GRBs are from different categories of sources? How many must we see to determine this?
- What S/N do we need to distinguish BNS from NS with low-mass BH?
- How much will kilonovae (or not) tell us?

Gen 2.5: Low Frequency

- Increased notification time: $T \sim f^{-8/3}$
- Eccentric sources, if they exist: $e \sim f^{-19/18}$
- IMBH, if they exist: $M_{max} \sim f^{-1}$
- But pushing to low freq is instrumentally challenging: Gen 3



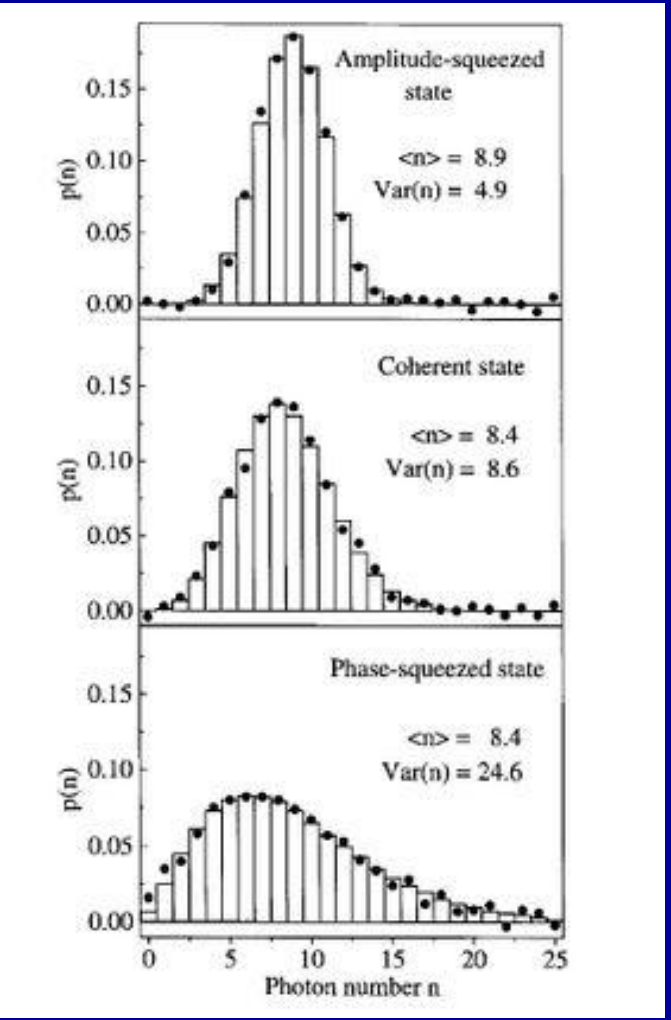
L. Wen 2002
Following Miller & Hamilton 2002

Gen 2.5: High Frequency

- Get both masses, not just chirp mass
- NS radius constraints depend strongly on high frequency sensitivity
- Oscillations of post-merger hypermassive NS (maybe)
- Photon squeezing provides promising path
  Ballmer talk

Fast Reaction Squeezing

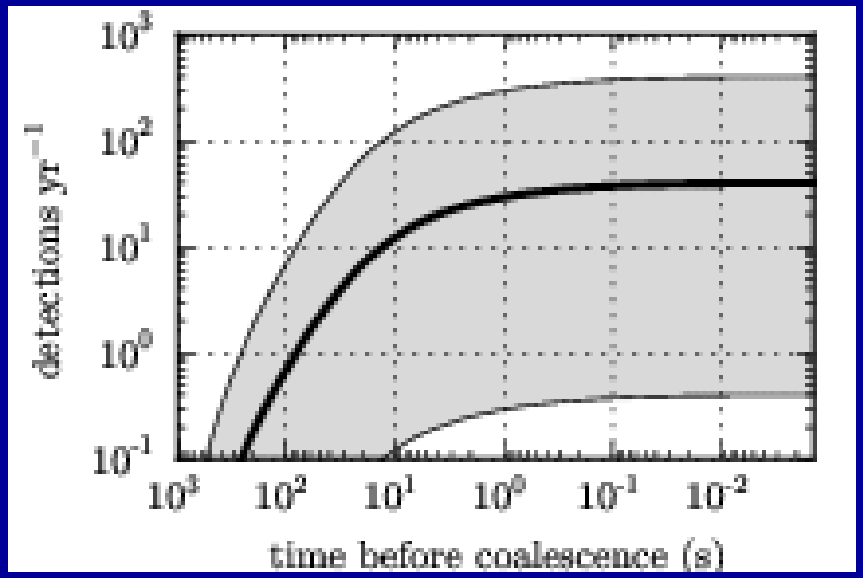
- What if we can't do freq-dependent squeezing?
- Can squeeze amplitude (<200 Hz) or phase (>200 Hz) noise
- Squeezing one worsens other
- Rana Adhikari and others feel that squeezing angle and magnitude can be changed rapidly
- E.g., minimal squeezing but ongoing coalescence triggers maximal phase squeezing after 200 Hz



From Wikipedia

Rapid Data Analysis

- Cannon et al. (2012) discuss strategies for identification of ongoing coalescence
- Reduced set of basis filters etc. can identify ~strong CBC ~10s before merger
- Lot of work, but >=6dB sensitivity boost at high freq
- Would mean that high S/N events dominate constraints



Cannon et al. 2012

Interpretation: Nuclear Physics

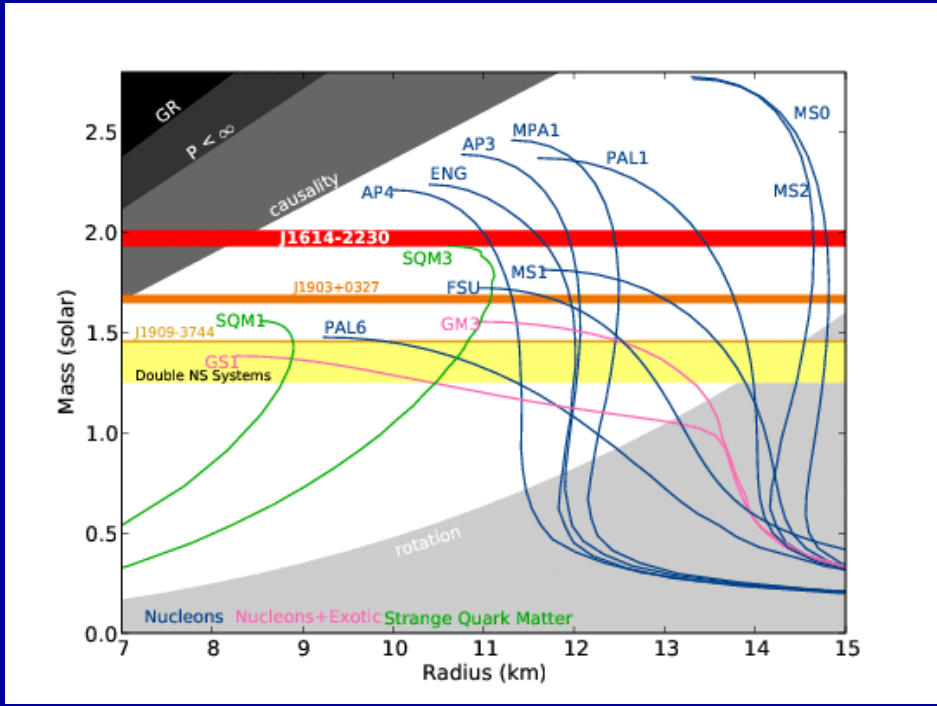
- Measurements of many precise R, M of NS from GW will allow us to stitch together $P(\rho)$ at T~0
- But is there a way to get at the dominant composition (nucleons, hyperons, quarks)?
  Reddy: not easily; transport properties?
- Are there any other GW+EM measureables that could help nuclear physicists?
  Read: no mo info from tides?
  Shibata: oscillation modes smeared

Interpretation: Binary Lives

- When many GW events are seen, what aspects of binary models can be established uniquely? Right now we are underdetermined, so the overall models are not really testable
- Can population synthesizers name plausible outcomes that would rule out (not just "constrain") their basic assumptions?

Ordinary vs. Extraordinary

- Which teaches us more: rare special events or common ordinary events?
- 2.3 M_{sun} or 1.0 M_{sun} NS?
- Black hole with mass less than 2 M_{sun}?
- Unusual mass ratios?
- <2 ms NS in BNS?
- What if none of these, e.g., all events are BNS between 1.25 and 1.44 M_{sun}?



Demorest et al. 2010

How Many Events do We Need?

- Depends on the diversity of what we see!
- If 10 events in 3 years give us NS-NS, NS-BH, BH-BH, and broad range of M_{NS} and S/N, we might be okay
  But pop. synth. still underdetermined
  If we believe pop. synth., could *lack* of some types of events be useful?
- Otherwise, qualitative advances require more events
  Also need enough for real-time squeezing

Conclusions

- Arguments exist for low and high frequencies, but instrumentation is much easier for high
- Very fast data analysis will be highly useful for extracting most info from CBC
- The interpretational framework is improving rapidly, but how will we disentangle many possibilities?
- Let’s hope for surprises!