The case for broadband high-frequency detectors

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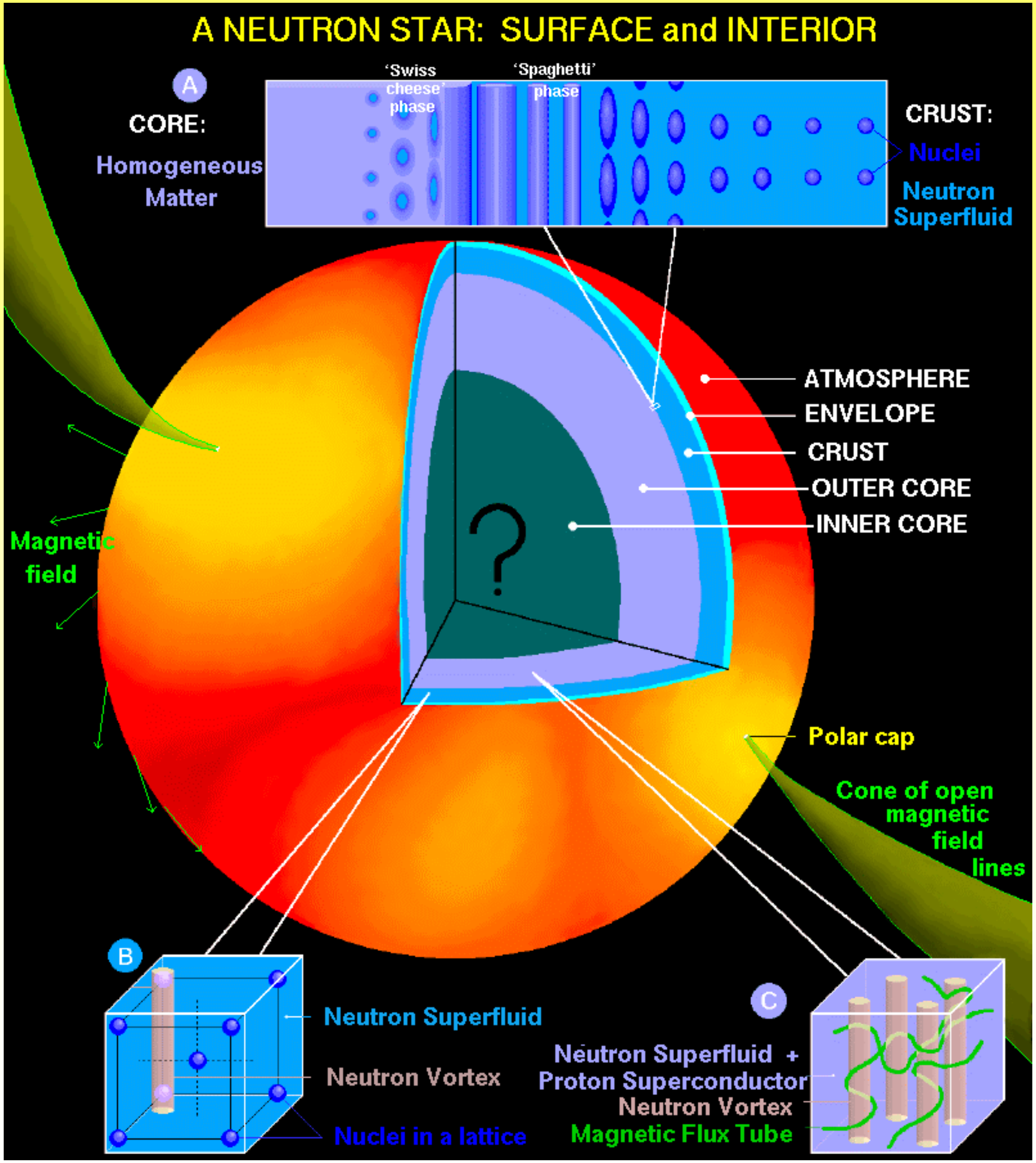
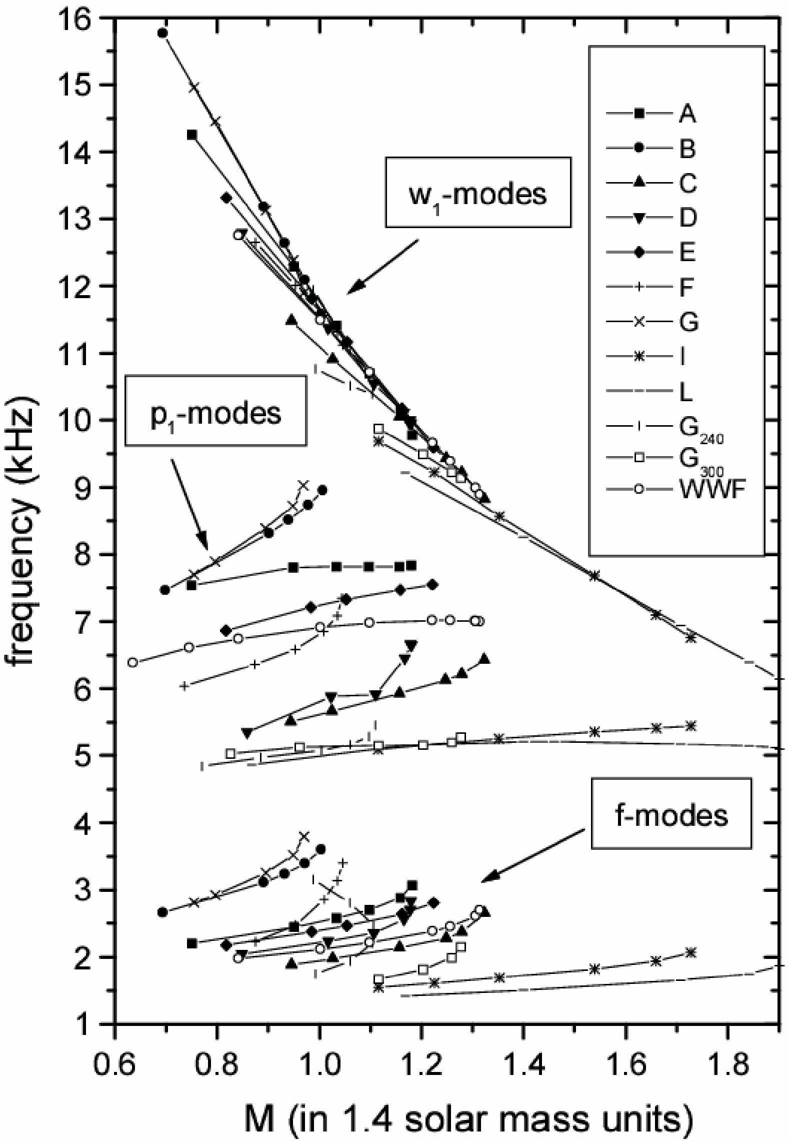
Possible sources at f > 2 kHz

- Neutron stars in binary orbits: mergers, disruptions with black holes.
- Formation of neutron stars: ringdown after initial burst.
- Neutron star vibrations, wide spectrum up to 10 kHz. Can be excited by formation, merger, or glitches.
- Stochastic background of primordial origin
- Speculative possibilities:
  - Black holes below 3 $M_\odot$
  - Compact objects in dark matter
  - Thermal spectrum at microwave frequencies, but only if inflation did not happen!

Neutron star physics

- Neutron stars are among the most complex and interesting physical systems
- Determining normal mode frequencies could illuminate the structure of neutron stars in the way helioseismology has allowed us to look inside the sun.





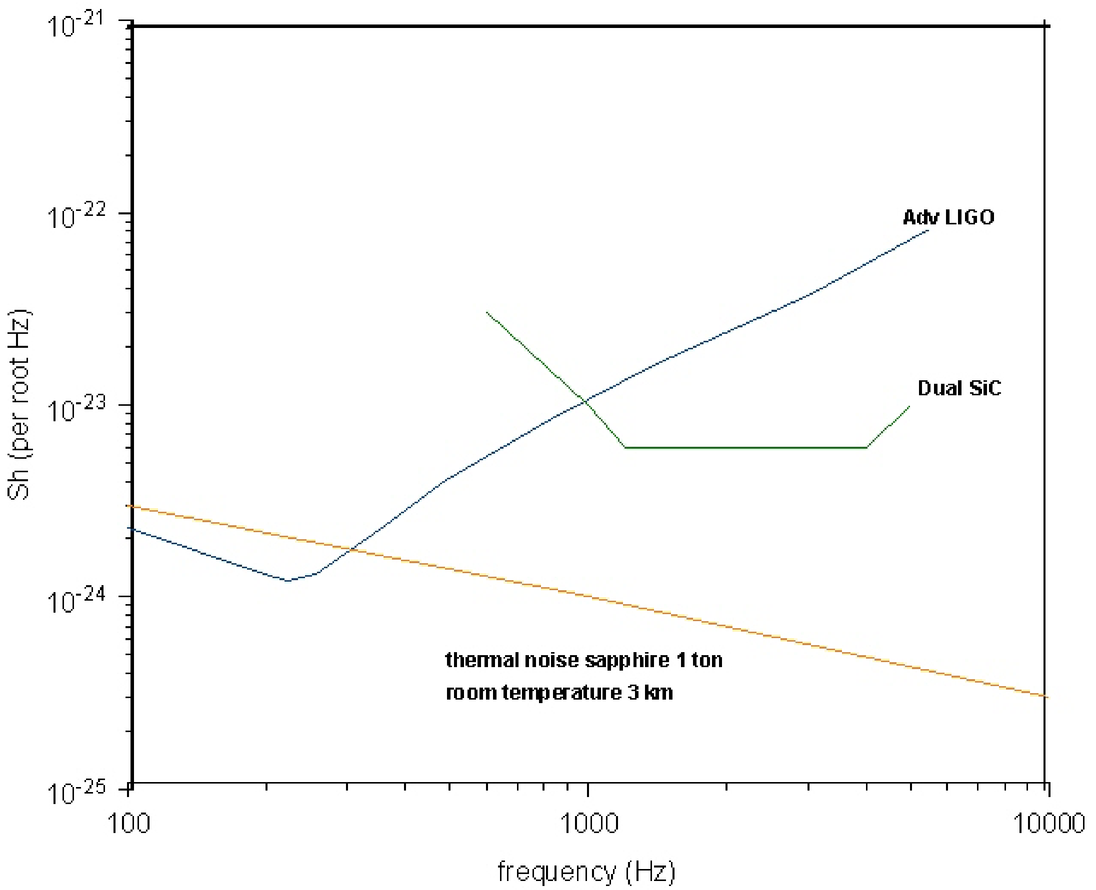
Oscillation frequencies of neutron stars

- Figure from Kokkotas & Andersson, gr-qc 0109054, shows modes of non-rotating stars
- Modes could be excited by violent events or by more modest **glitches**.
- Glitches occur often in young pulsars, making Crab a good target.
- Glitch energy $< 10^{-10} M_{\odot} c^2$

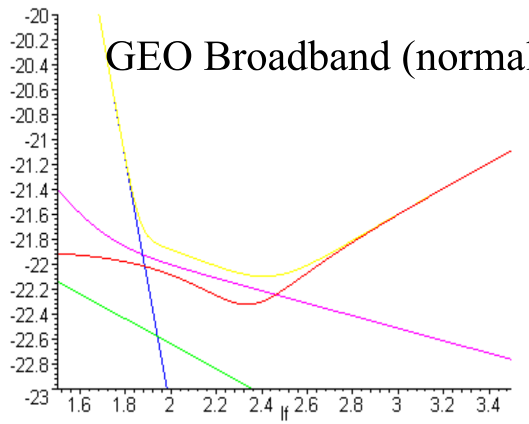
Stochastic Background

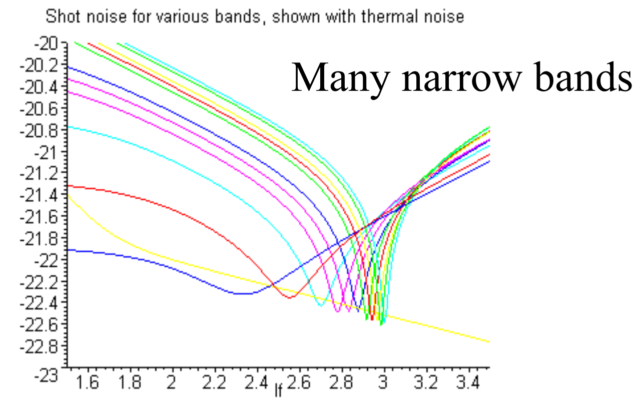
- Only firm limit at high frequencies is $\Omega_{gw} < 10^{-5}$, from cosmological nucleosynthesis.
- Inflation predicts $\Omega_{gw} < 10^{-15}$
- Many mechanisms have been proposed to generate backgrounds between these limits, some relying on string physics or branes.
- Expected astrophysical backgrounds are **stronger** than the inflation bound over most of the observable GW spectrum. The 10 kHz band is an exceptionally clean window in this way.

Possible detector strategies

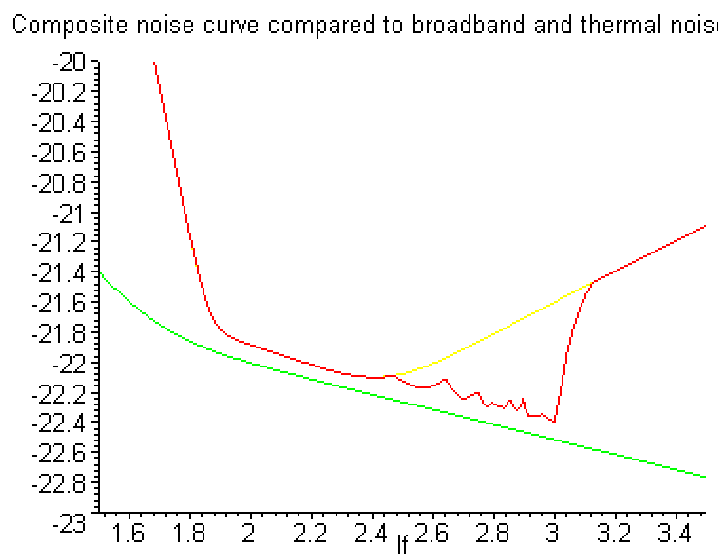


Synthesizing a broadband detector at high frequencies -- current GEO600 capability

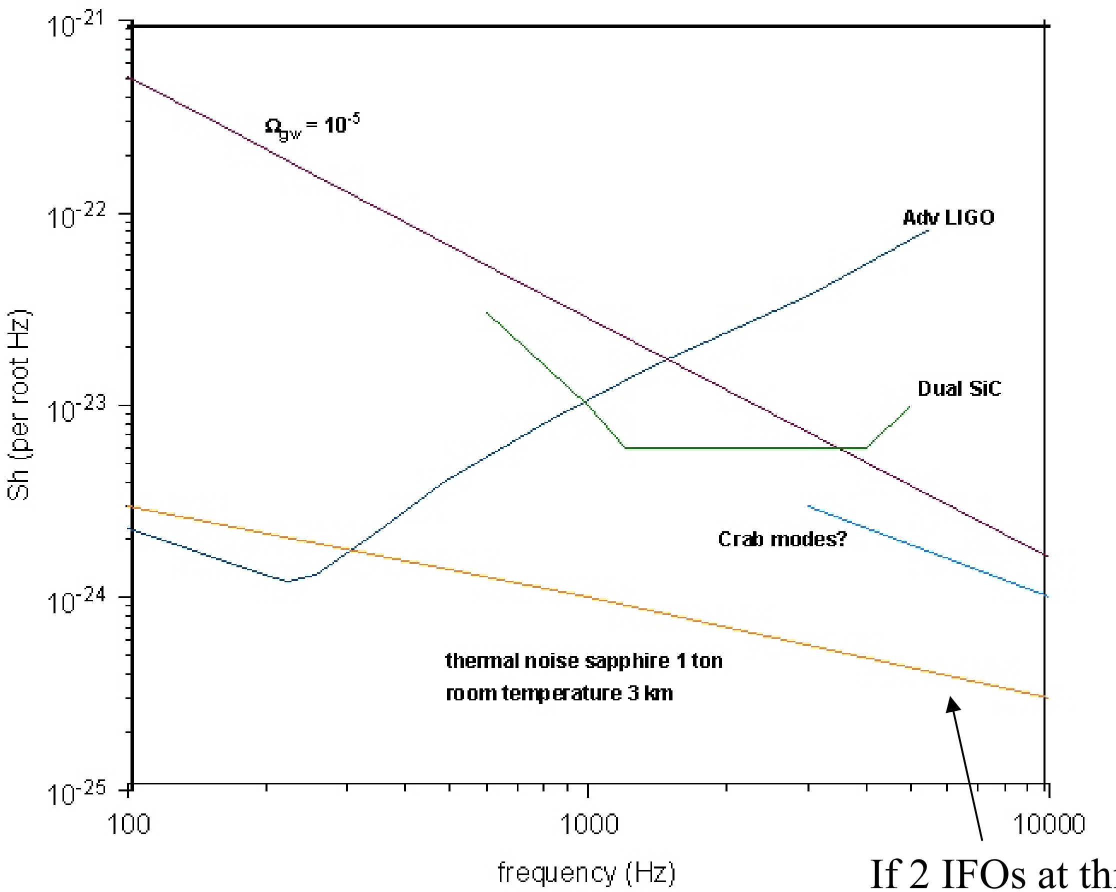




Synthesized broadband detector. GEO will use this for pulsar search, one band after another



Source strengths



Crab: assume 10^{-12} Mc^2 energy

If 2 IFOs at this sensitivity are cross-correlated, they can reach $\Omega_{gw} = 10^{-13}$, better than Adv LIGO or LISA.

Interferometers at high frequencies

- Interferometers have potentially extremely good high-frequency sensitivity. By implementing simultaneous multi-band signal recycling, they can synthesize a broadband instrument.
- While an interferometer like Advanced LIGO could implement this strategy, it would be expensive compared to resonant-mass detectors that improve over LIGO’s standard power-recycled sensitivity. There would also be severe operational constraints from competing observing goals.
- A third-generation detector could implement this as standard, but this might force design compromises with its low-frequency goals, where seismic noise, gravity-gradient noise, and the quantum “limit” are design drivers.
- GEO600 is planned to become a platform for implementing HF techniques once it is eclipsed by Advanced LIGO.

A dedicated high-frequency interferometer

- Our third-generation strategy for interferometers should be to address low- and high-frequency extensions with *separate* IFOs.
- An interferometer dedicated to high frequencies could be much less costly. Sacrificing LF sensitivity offers big cost savings:
  - Seismic isolation can be relatively crude.
  - Arm-length can be shorter and still give good performance.
- Technological challenges demanding but not necessarily costly:
  - Thermal performance crucial: sapphire or silicon masses, ultimately cryogenic.
  - Broadband operation requires very high laser power: diffractive optics.
- A carefully designed HF-IFO performing better than the limits shown earlier could be built in parallel with Advanced LIGO, enabling *neutron star seismology* before the end of the decade.
- Two such instruments near to one another might be the most realistic and inexpensive way of reaching the *inflation bounds* on a stochastic background.