Superconducting antenna concept for gravitational waves

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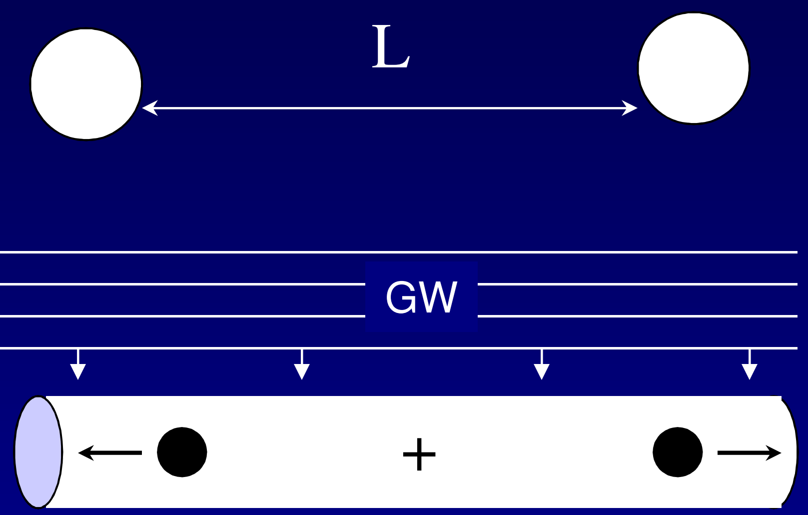
LIGO: $h \sim 10^{-23}$-10^{-24}

Crab pulsar: $h \sim 10^{-26}$

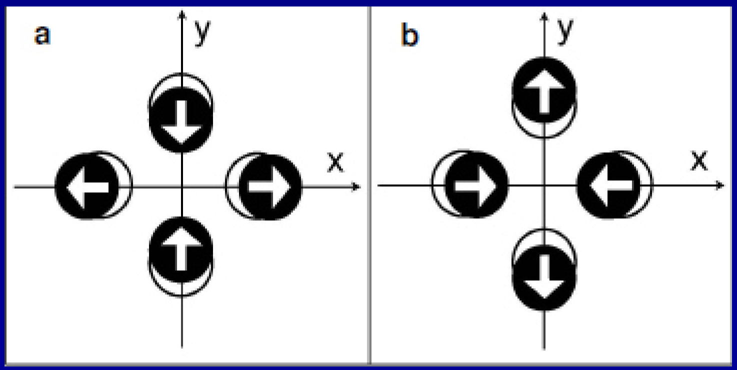
Summary on Novel Antenna:

- Concept exploits quadrupolar action of GW on bimetallic superconducting antenna.
- The antenna transforms part of the GW energy into the motion of superfluid electrons; the motion is detected electronically.
- This design avoids Coulomb blockade of the electronic motion.
- Technical realization of the antenna may require technology development, but there is no showstopper.
- These devices will be able to detect gravitational waves with amplitudes as low as $h_0 \sim 10^{-26}$: Crab Pulsar is within the reach.
- Such sensitivity could be obtained at spatial scales smaller than 10 meters.

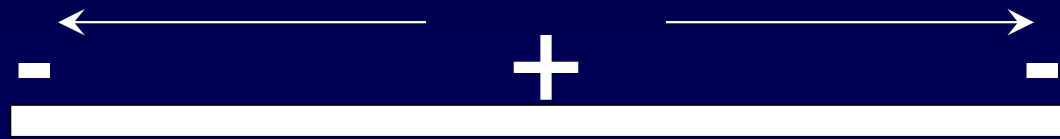
Starting Point



$$\Delta L = L h_0 \sin \omega t$$



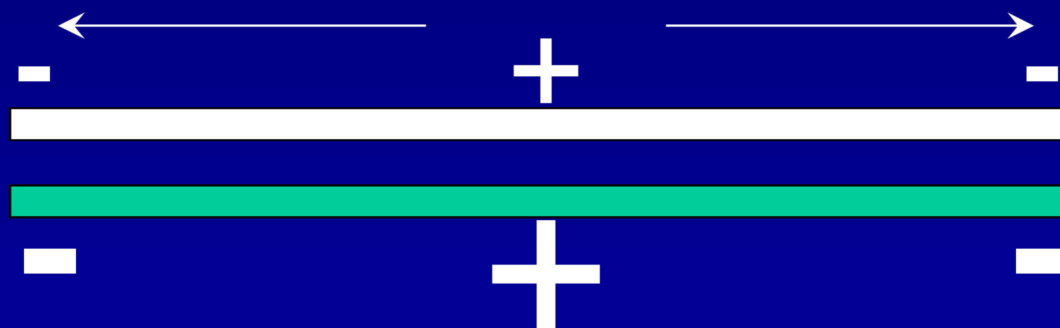
Tidal action on a metallic wire



How to measure this?

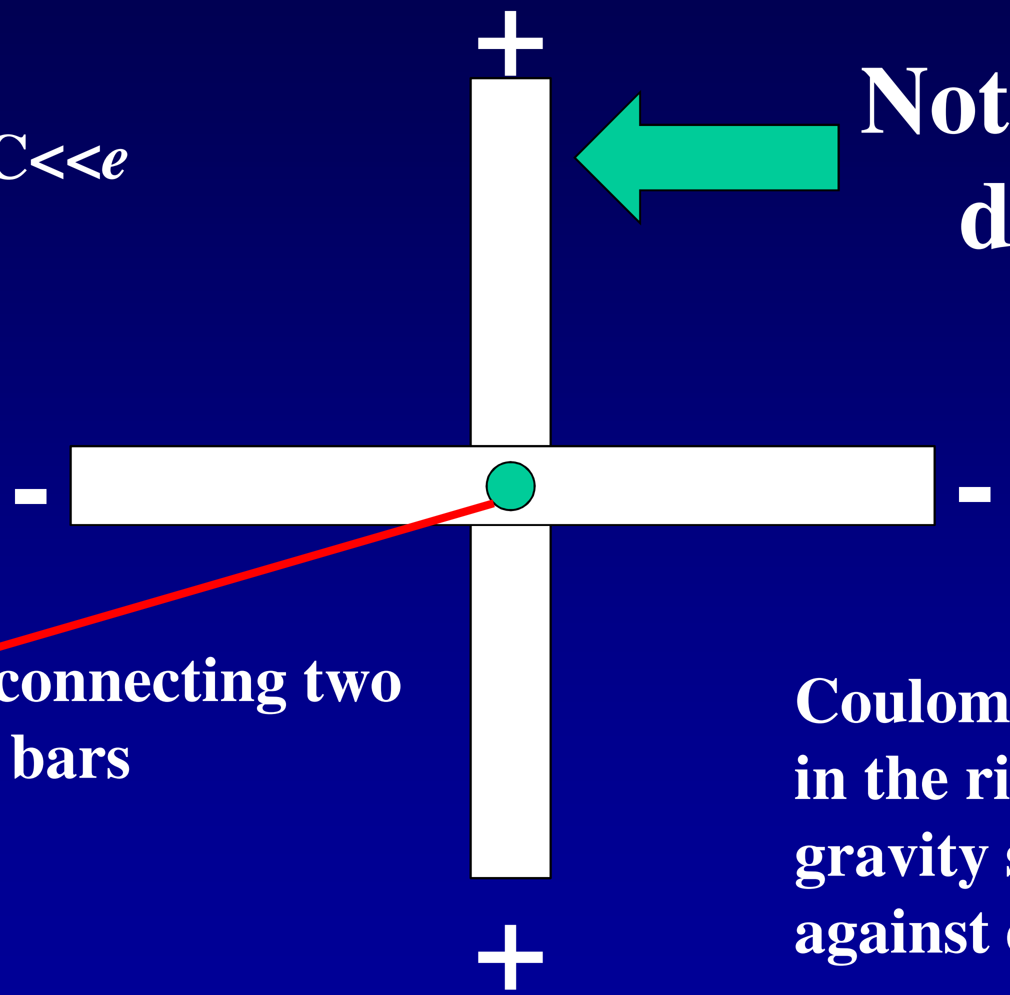
R. Adler, 1976 : take two of them!

(Long conductors as antennae for gravitational radiation. *Nature* 259, 296-297.)



Quadrupolar tidal action on a wire:

$q = VC \ll e$

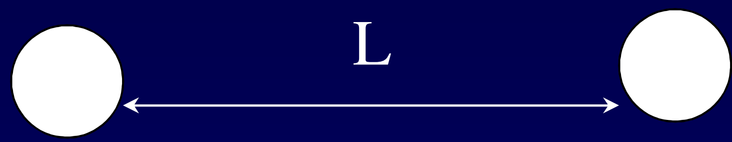


Not the best design!

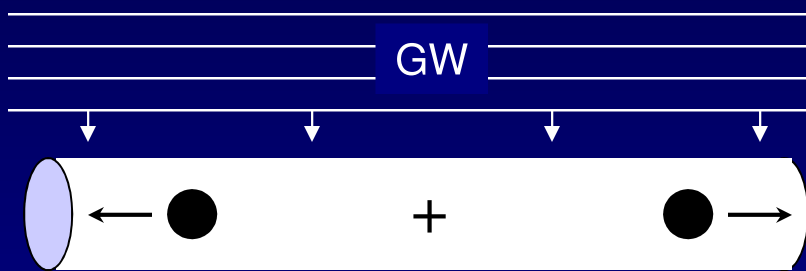
A bridge connecting two bars

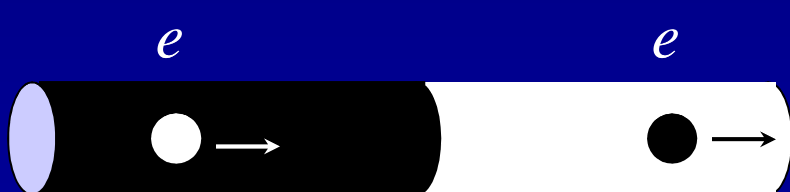
Coulomb blockade:
in the right design gravity should not fight against electromagnetism

Thinking continued:

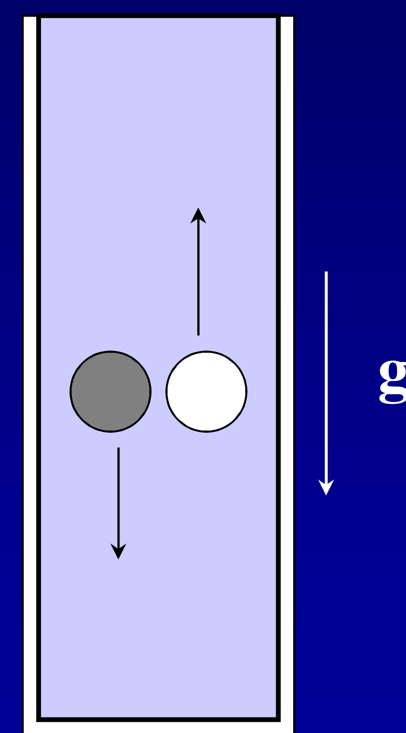


$\Delta L = L h_0 \sin \omega t$

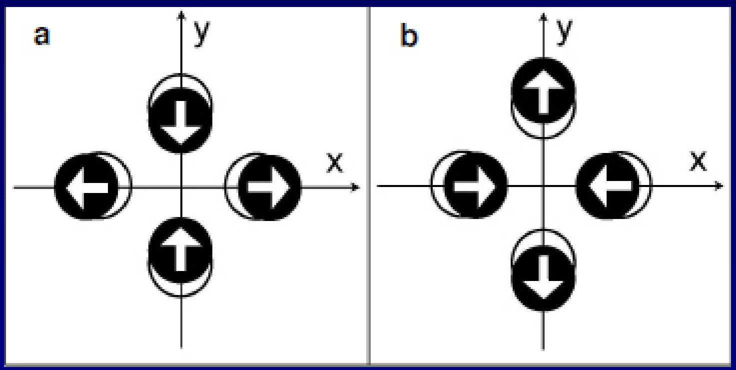


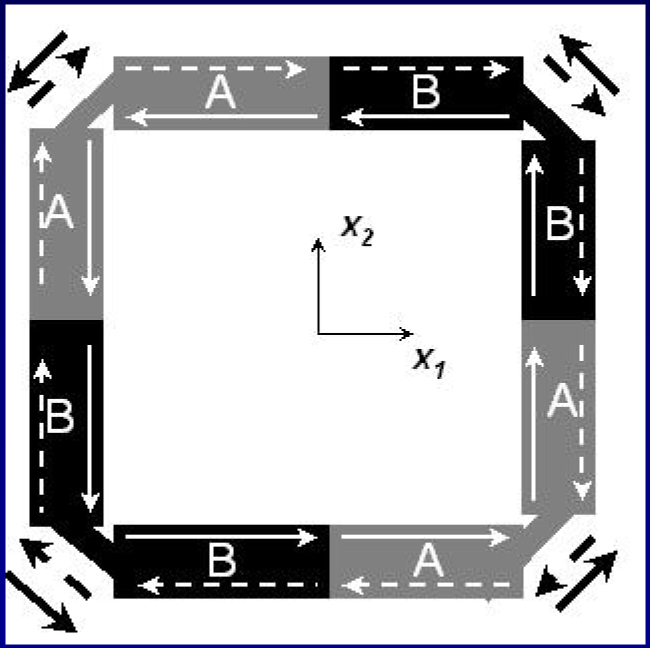


Bimetallic bar, negative m_{eff}



Circular current, no charge accumulation





Seems like possibly right design.
Bi-metalisity breaks the symmetry!

Why Superconductivity:

Motion of electrons in semiconductors and normal metals, though sometimes called “free”, is Aristotelian: it persists while the force is acting. Ohms law: j~v~*e*E~F,

v~F , *i.e.*, velocity in response to force

In superconductors *d*v/*d*t~E, *i.e.*, motion is Newtonian!

This difference has crucial consequences:

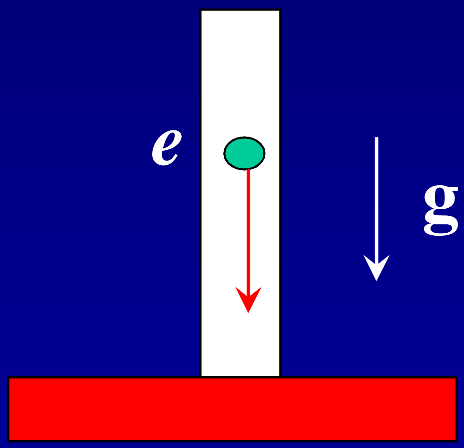
•S/C current response is greater by a factor $(\omega\tau)^{-1} \sim 10^{10+}$. Ten or more orders of magnitude more than justify SC.

•Price to pay: no negative masses for SC. Cooper pairs have a positive mass.

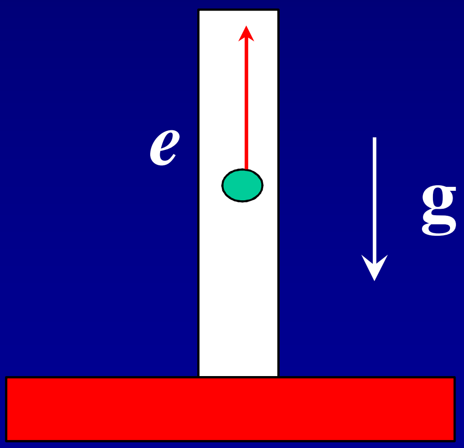
•Moreover, it looks like $m_{CP}=2m_0$!

Motion of electrons in gravity field: *Quo Vadis?*

Frozen lattice



Unfrozen lattice



Frozen lattice

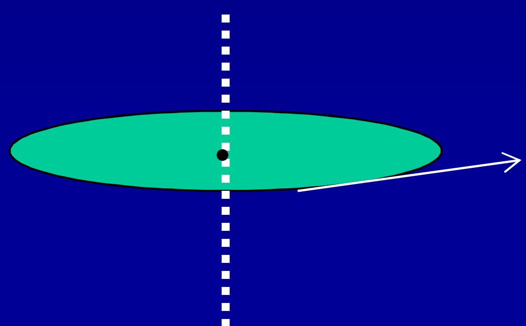
1968

Unfrozen lattice

$$E = -mg/e$$

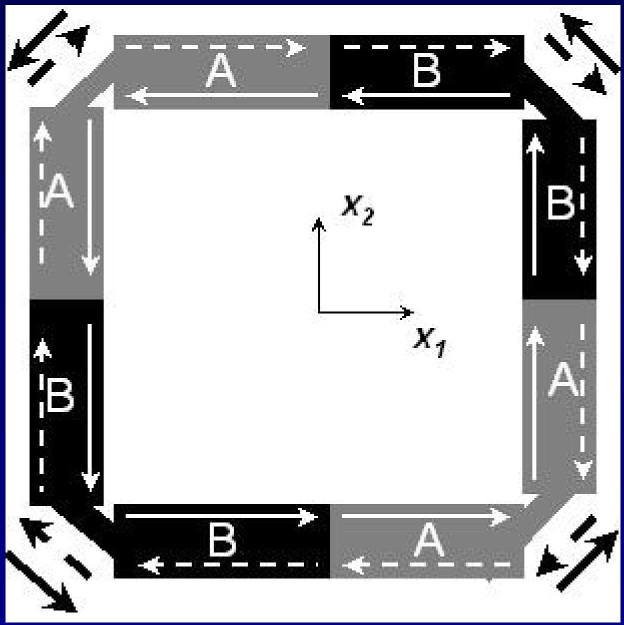
$$E = \alpha Mg/e$$

Dessler A.J., Michel F.C., Rorschach H.E. ,Trammel G.T. Gravitationally induced electric fields in conductors. *Physical Review* **168** (1968) 737-743.



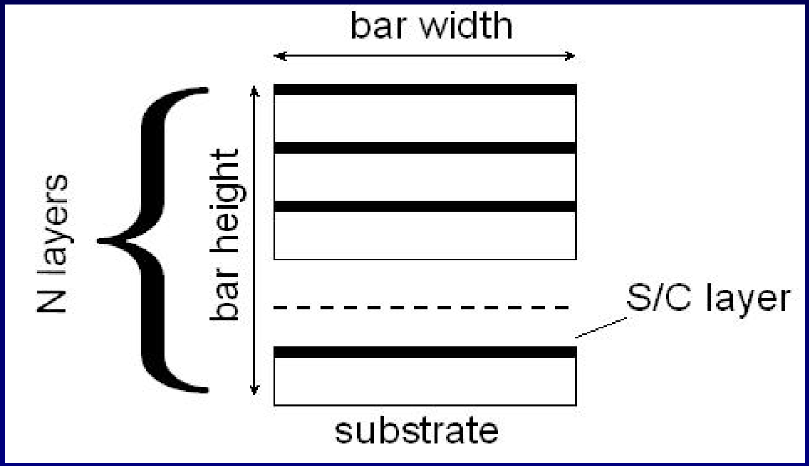
Beams J.W. Potentials on rotor surfaces. *Physical Review Letters* **21** (1968) 1093-1096.

Some numbers

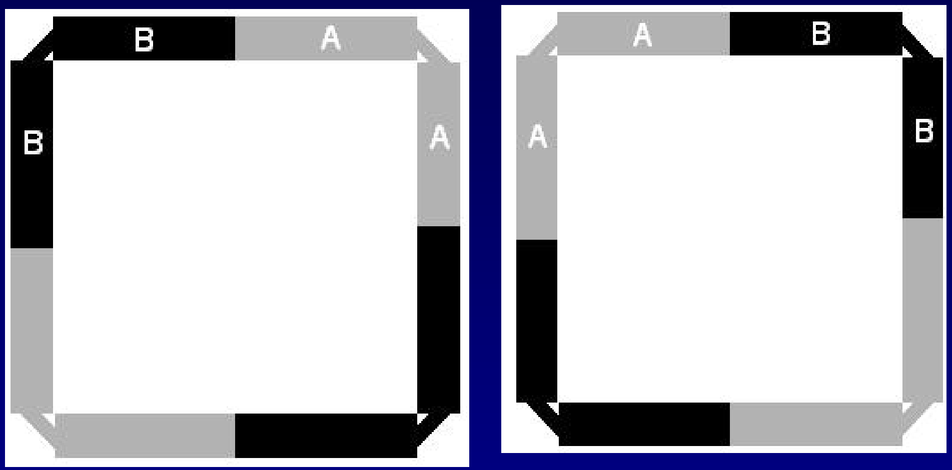


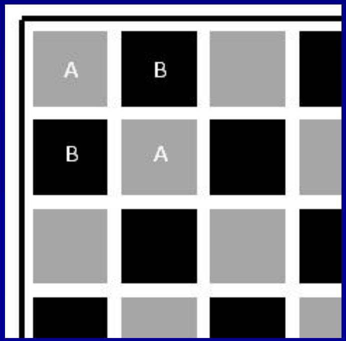
From Crab pulsar ν~60Hz, h~10^{-26}, the energy flux density on Earth's orbit ~ 10^{-10} *ergs*/(*cm*^{2} *s*). ➔ Current for 10x10cm^2 cross section of conducting loop is I~10^{-13}A. E_{kin}~10^{-39} ergs. Efficiency is 10^{-31}.

"Spaghetti" Structure



layers with A and B swapped

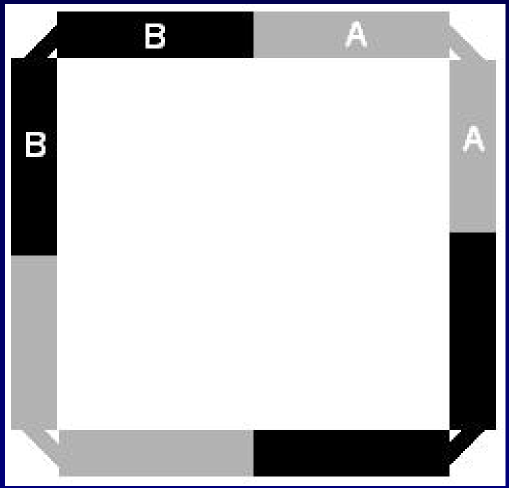


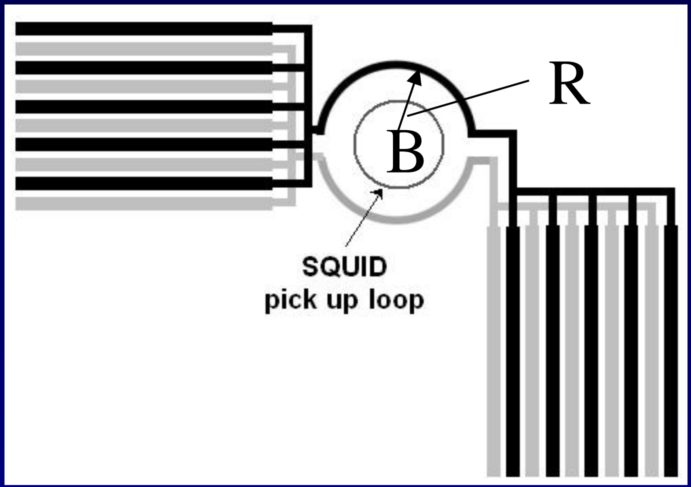


cross section

- Currents move in opposite directions and cancel the magnetic field.
- The number of spaghetti depends on geometry; large but realistic.

Readout





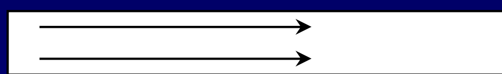
At $I=1\ fA$ and $R=5\mu m$, $B=\mu_0 I/(2R) \sim 10^{-16}\ T$.

SQUID noise floor $3fT/Hz^{1/2}$: $10^{-17}\ T$ /1 day of measurement. Freedom to exploit, say, *10* SQUIDs for different groups of layers, and/or get to weaker GW source detection, and/or reduce the observation time.

Noise Floor of the Detector

- Real noise floor of this antenna is due to normal resistance

I_n, I_S



$$\left\langle I_n^2 \right\rangle = 4(k_B T / R_n)\delta\nu$$

- Two notes are important here:

1) at low *T* the normal fluid (and its influence) dies out exponentially;
2) bandwidth $\delta\nu$ can be made narrow for periodic signals (large integration time).

Our estimates indicate that achievable noise floor is about *10 fA/Hz*$^{1/2}$, which inspires optimism, since current is bigger: ~10^{-13}A.

Thank you!

Conclusions

•We elaborated a novel concept of the GW antenna. We see no showstopper for this concept and would welcome experts opinion on its viability.

•Hopefully, <u>in parallel</u> to other large-scale efforts, such as the LIGO approach and LISA mission or NANO gravitational initiative, the suggested concept will become useful for one of the most challenging experiments – the detection of gravitational waves.