

THE LIGO PROJECT

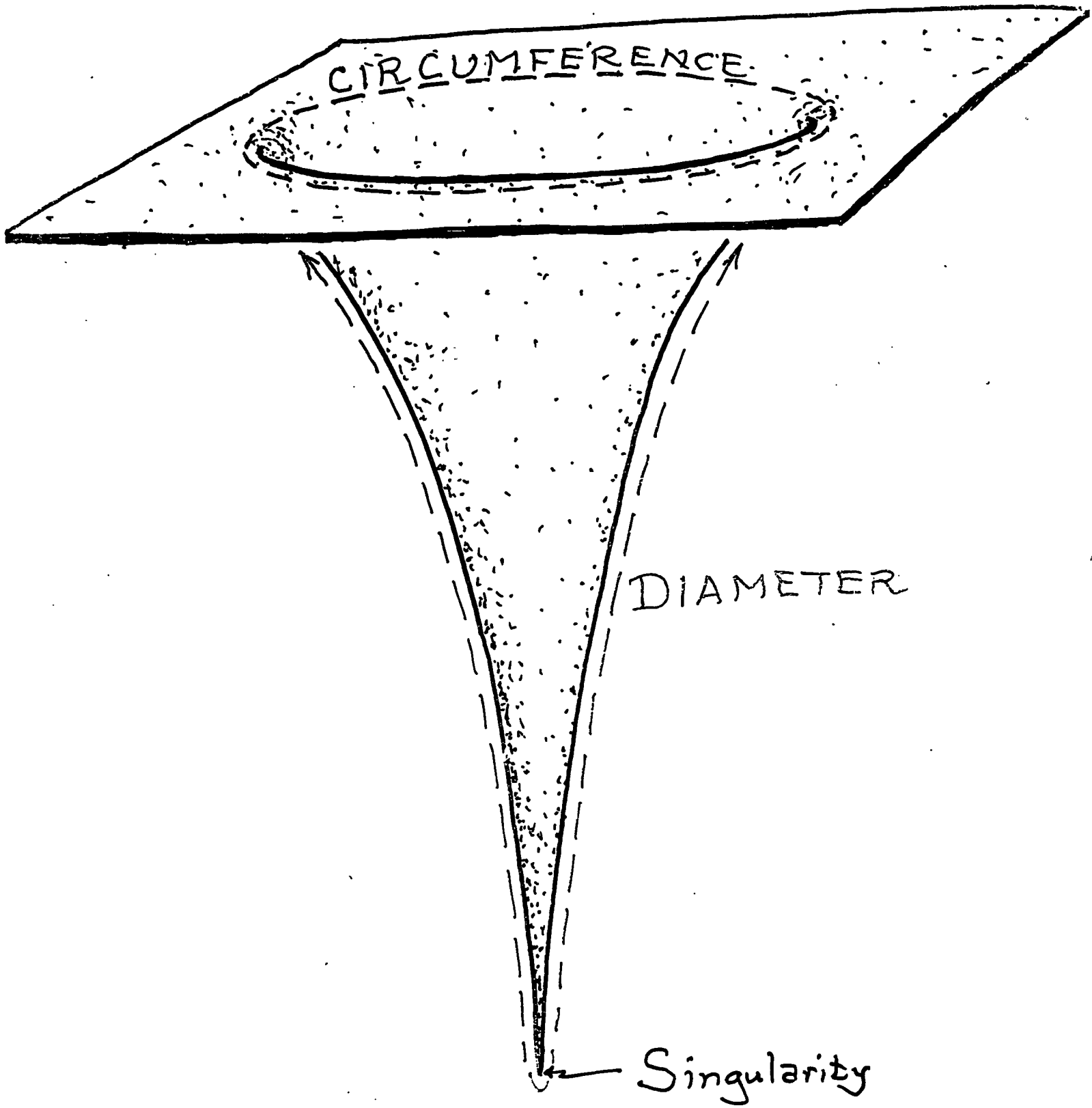
Kip Thorne

Caltech

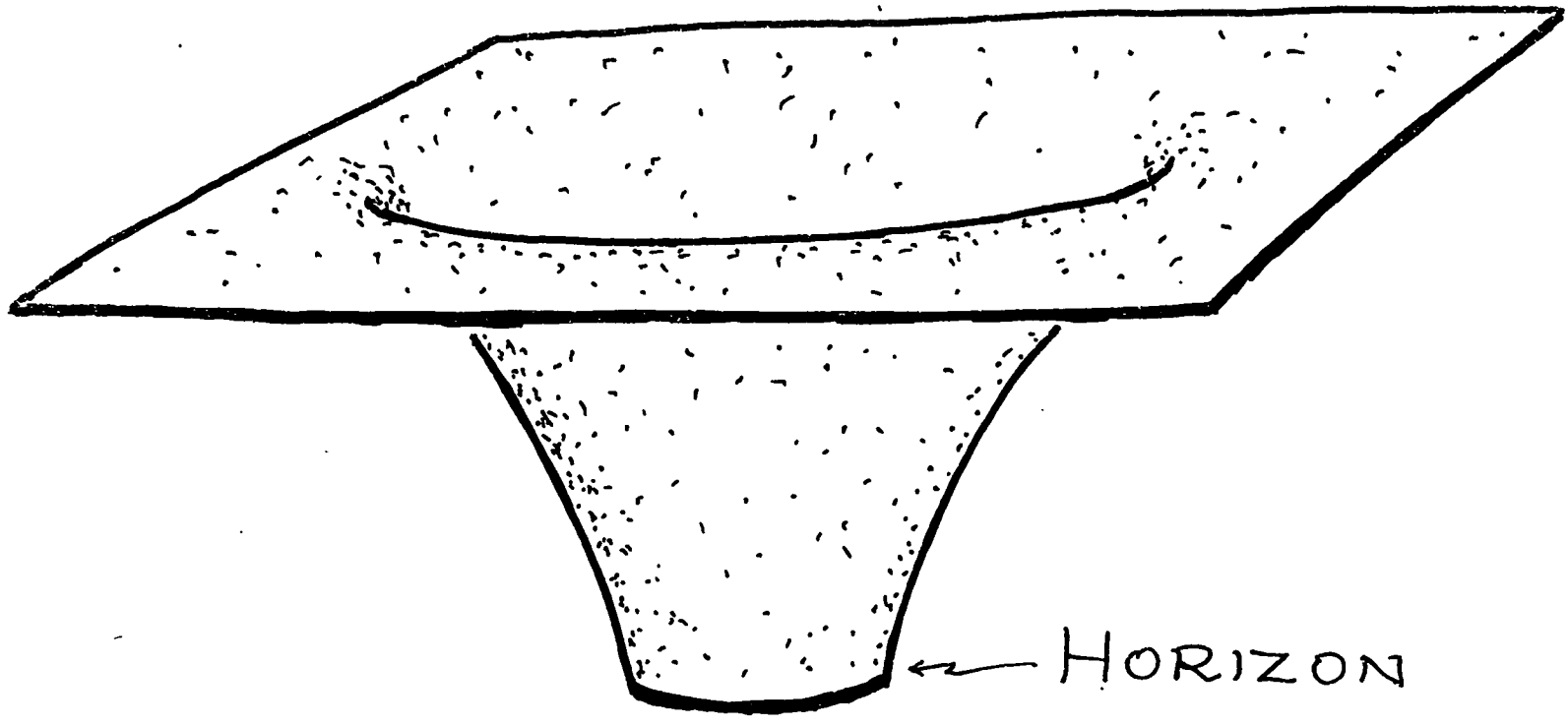
December 20, 1994

Ligo Vacuum Equipment Proposal Conference

LIGO-9940003-00-R

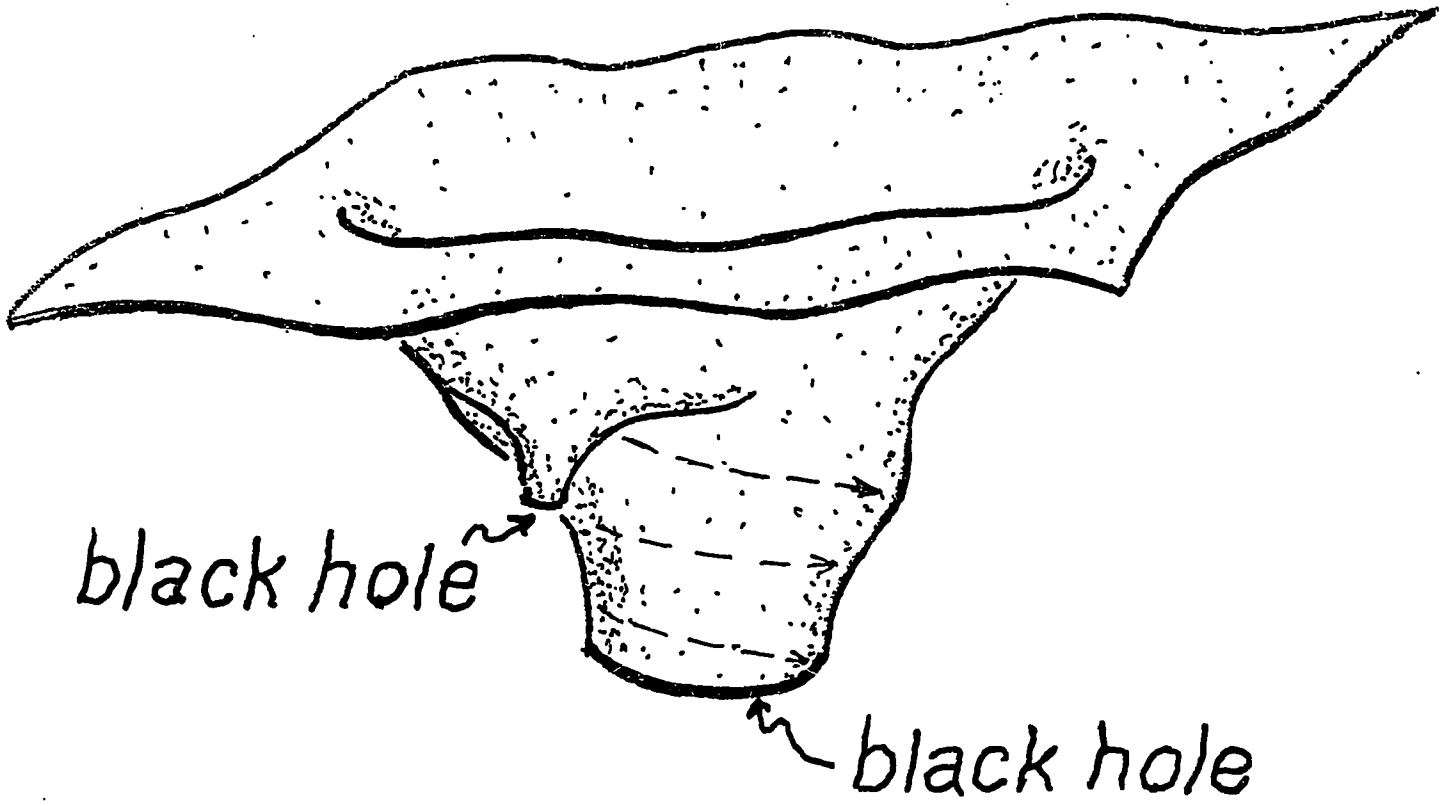


DIAMETER \gg CIRCUMFERENCE



The warpage of space
around a black hole

EXAMPLE: BLACK-HOLE BINARY

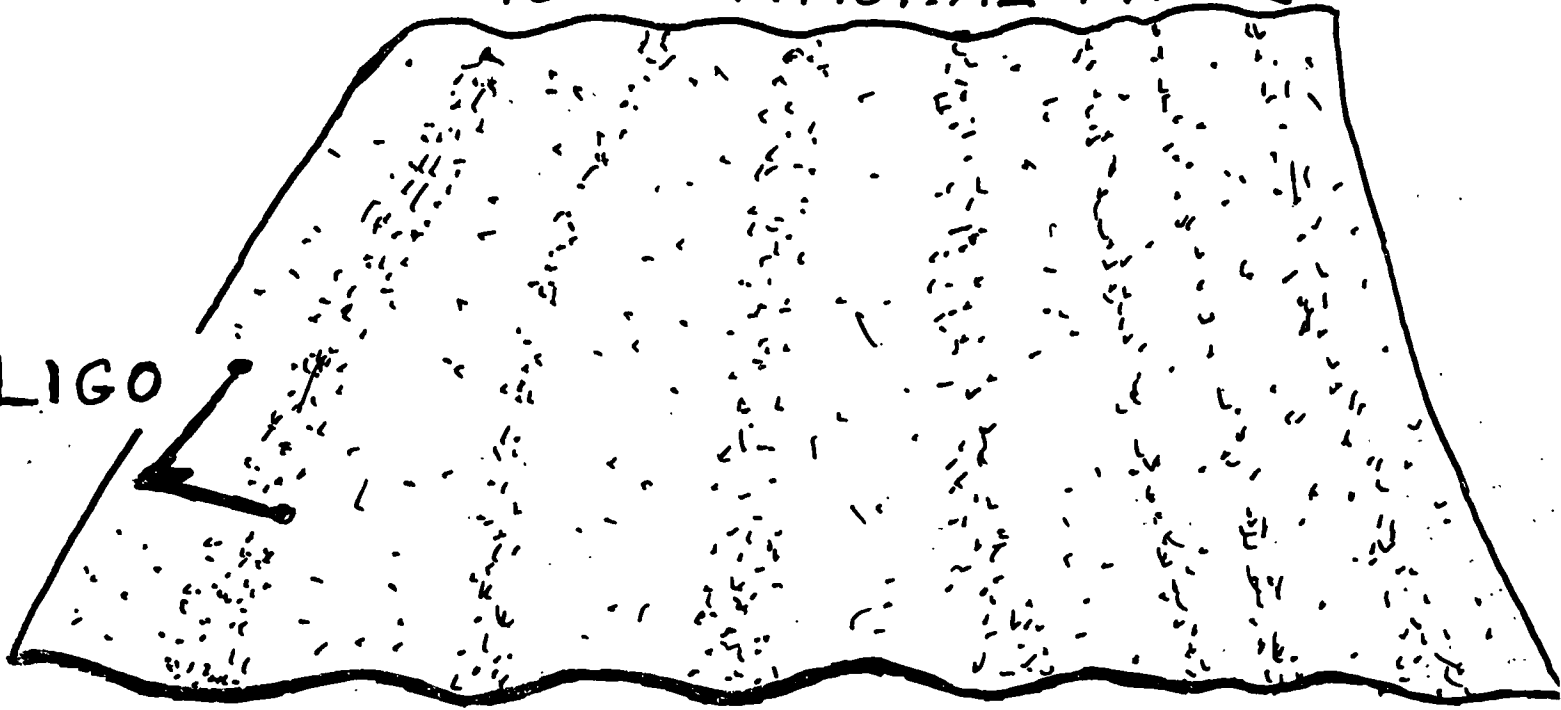


gravitational waves ↷

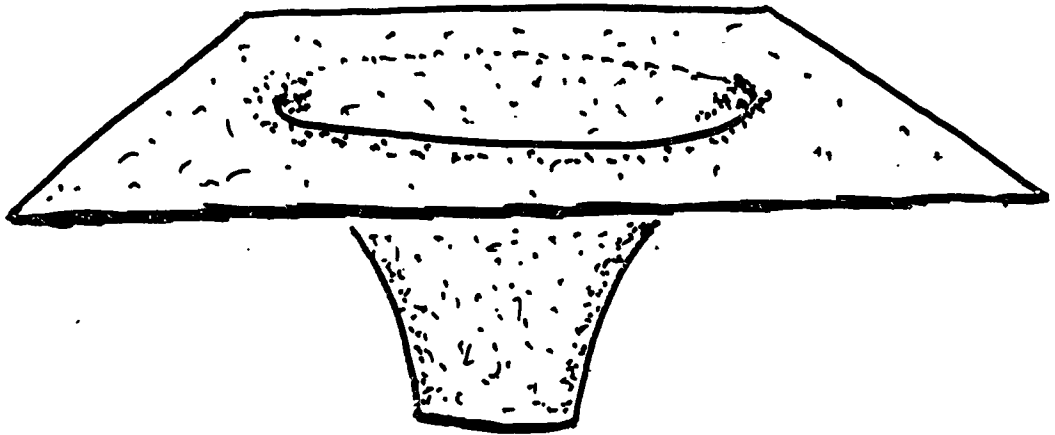
FIG 10.1

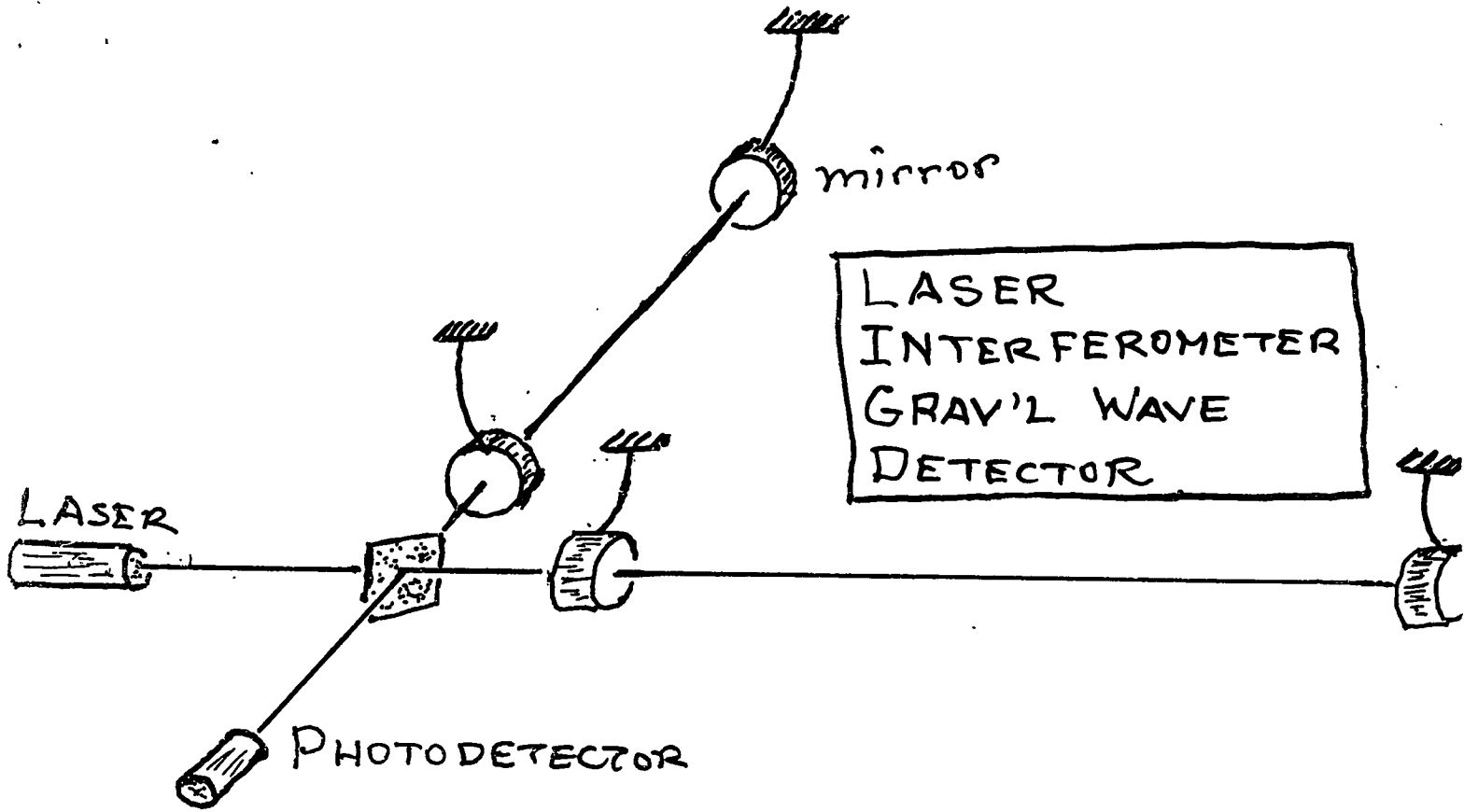
GRAVITATIONAL WAVES

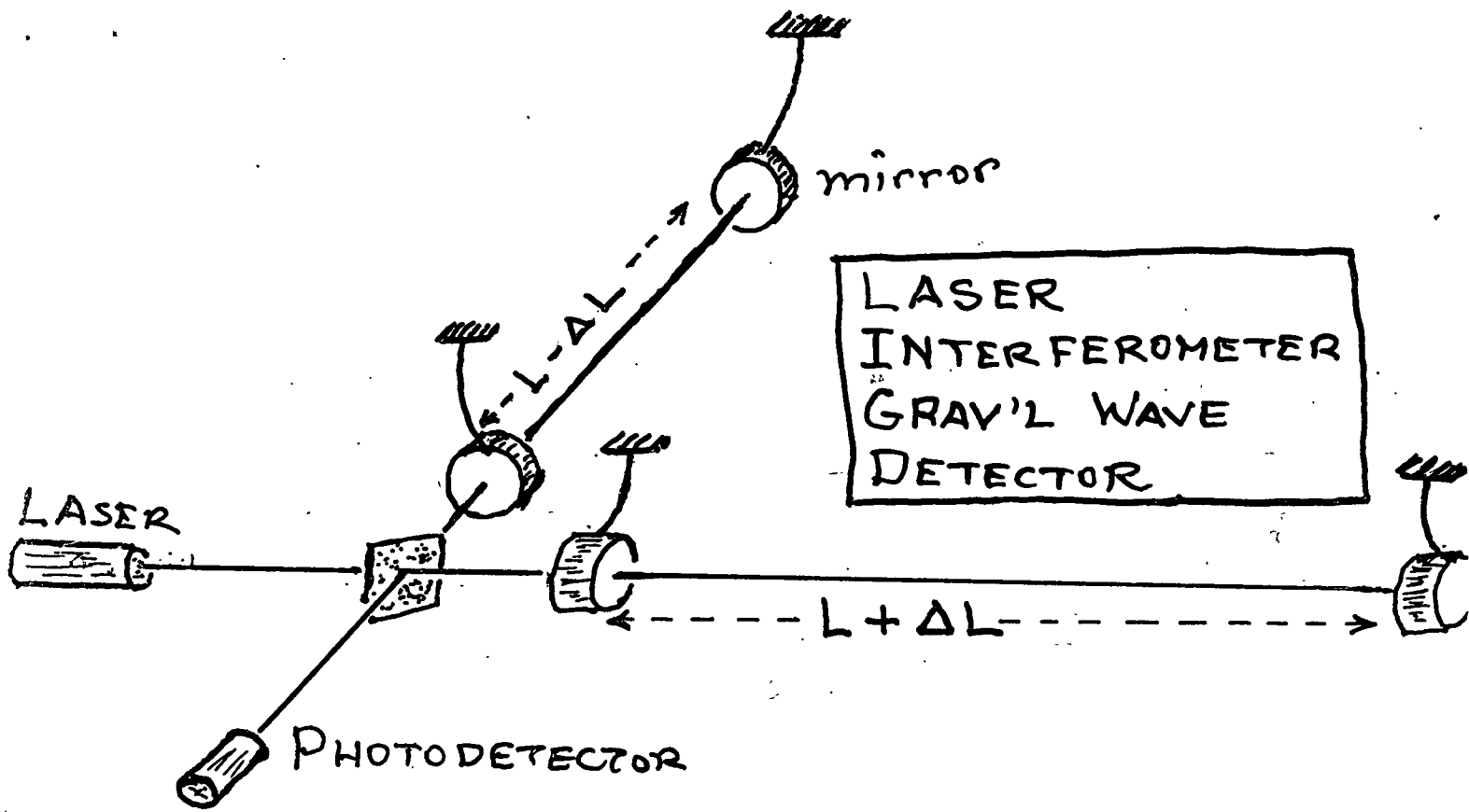
LIGO



MAP OF BLACK HOLE







$$\frac{\Delta L}{L} = \text{WAVE STRENGTH} \approx 10^{-21}$$

• IF $\Delta L = \frac{1}{10}$ millimeter,

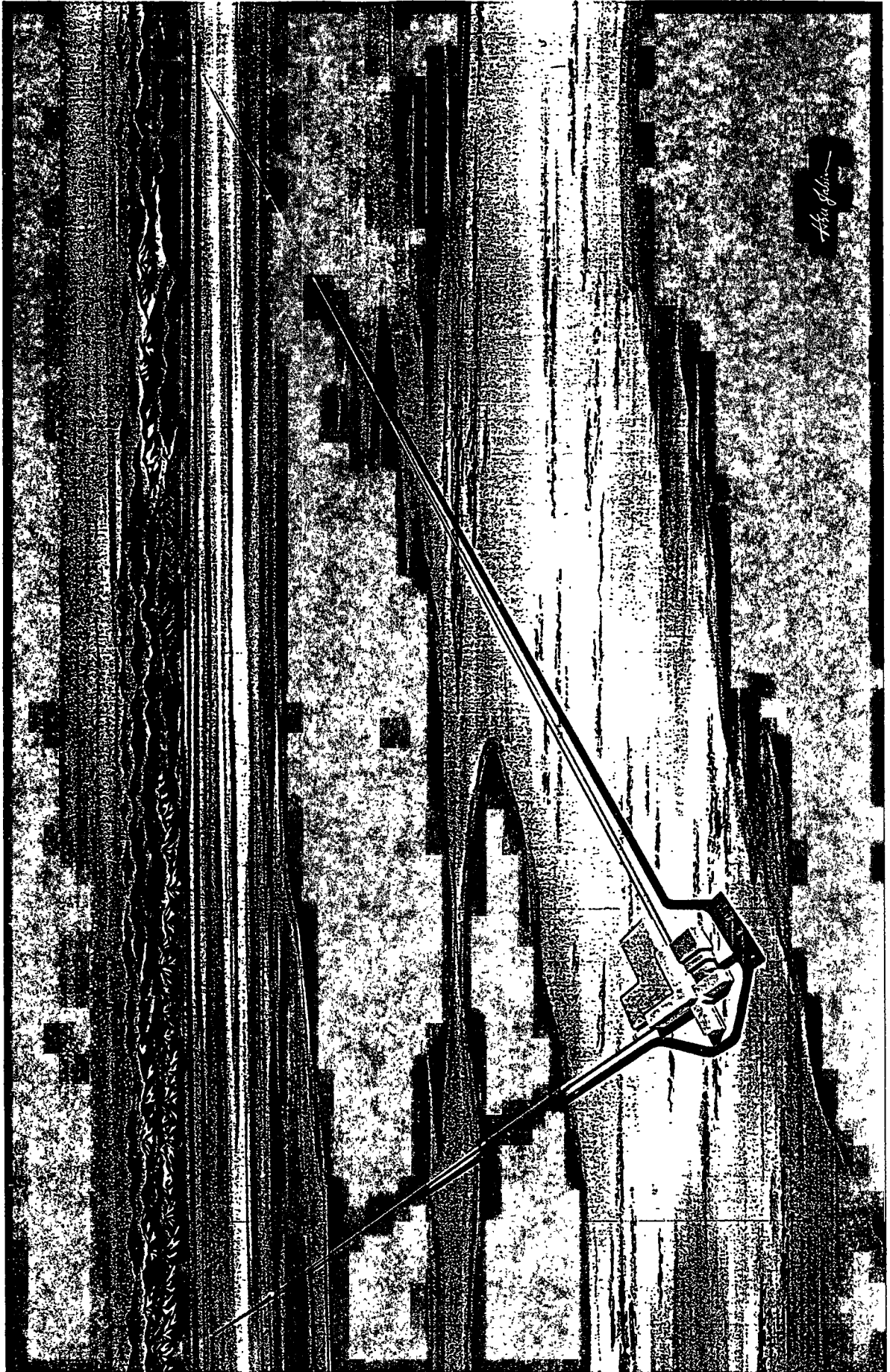
NEED $L \approx 3$ light years

• IF $\Delta L = 10^{-13}$ cm = (Diameter of atomic nucleus),

Need $L \approx 4000$ kilometer

• CAN MEASURE $\Delta L = 10^{-16}$ cm = $\frac{1}{1000}$ × (Diameter of atomic nucleus)

Build $L = 4$ kilometers



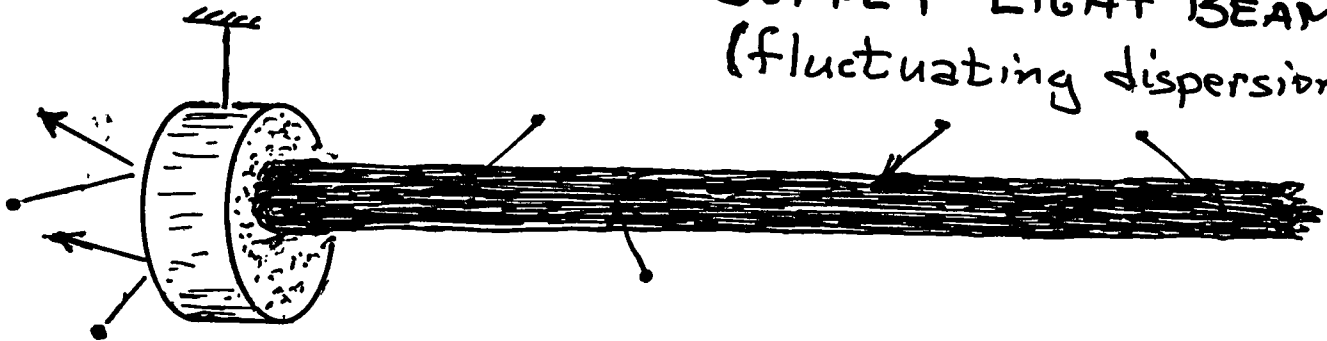
Aria fabric

HOW IS IT POSSIBLE TO MEASURE SUCH TINY MOTIONS (10^{-16} cm)?

• AIR MOLECULES:

BUFFET MIRRORS

BUFFET LIGHT BEAM
(fluctuating dispersion)



MIRRORS & LIGHT BEAM MUST BE IN VACUUM

• MIRROR'S ATOMS VIBRATE (thermal noise)

LIGHT BEAM FEELS 10^{18} ATOMS

ATOMS VIBRATE FAST: $\sim 10^{13}$ Hz

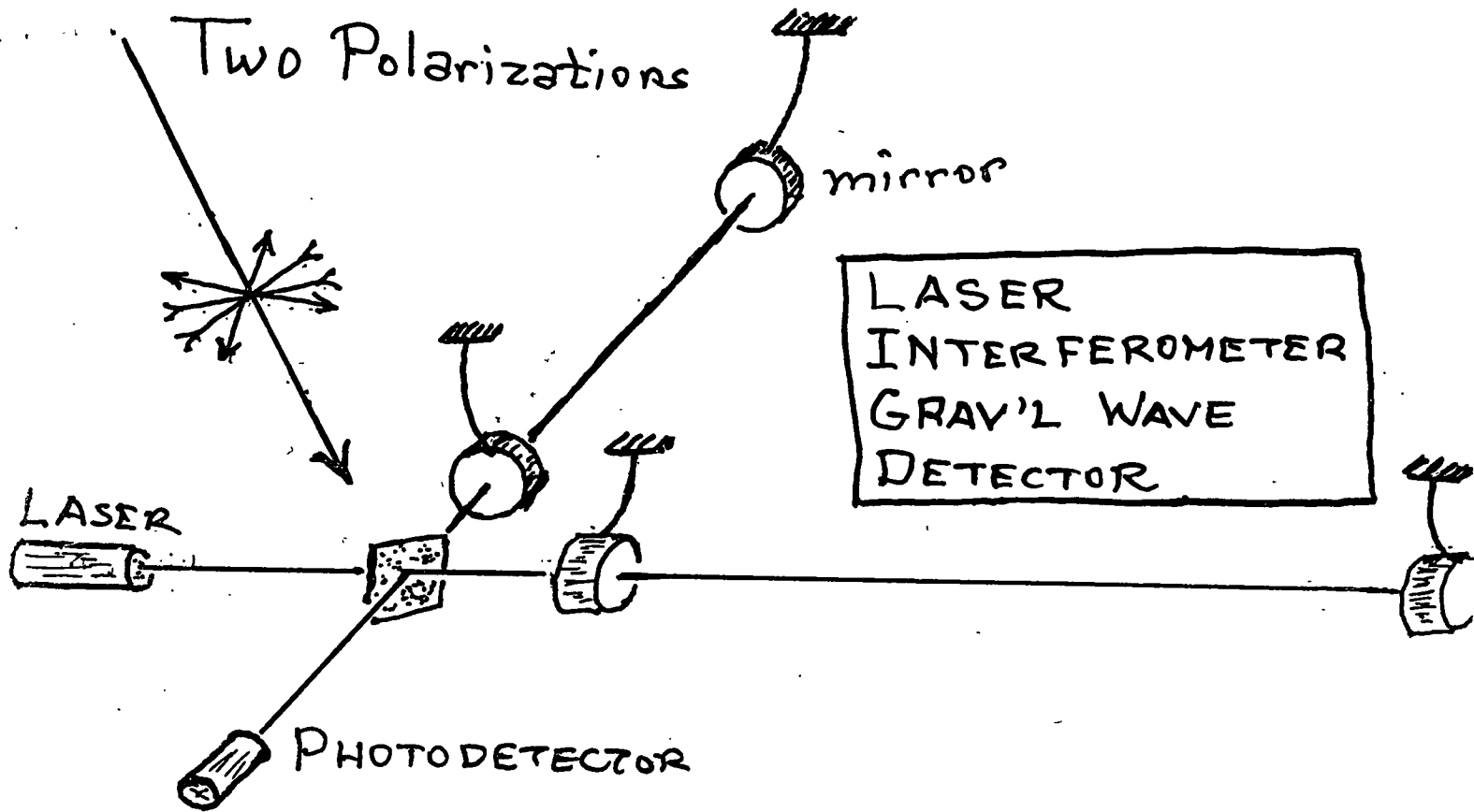
BEAM MEASURES SLOW VIBRATIONS:

~ 100 Hz

• EARTH VIBRATES AND SHAKES MIRRORS

ANTI-VIBRATION SUSPENSION

QUIET ENVIRONMENT

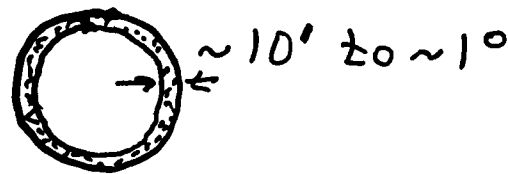


$$\frac{\Delta L}{L} \equiv h = F_+ \begin{matrix} \text{Antenna Patterns} \\ \text{(direction)} \\ \text{(orientation)} \end{matrix} h_+(t) + F_x \begin{matrix} \text{Waveforms} \\ \text{(direction)} \\ \text{(orientation)} \end{matrix} h_x(t)$$

- LIGO measures one waveform;

Hanford WA
Livingston LA

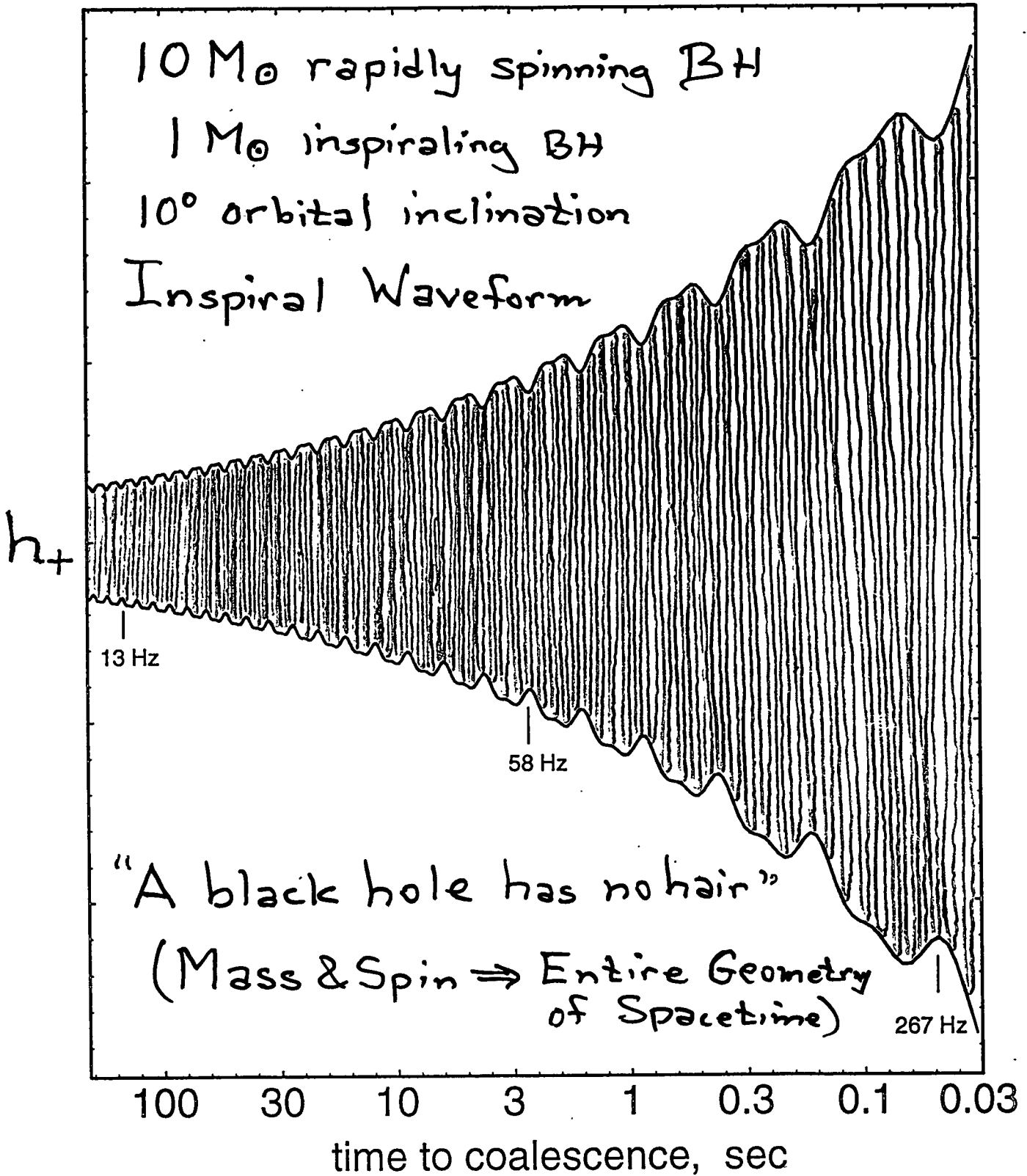
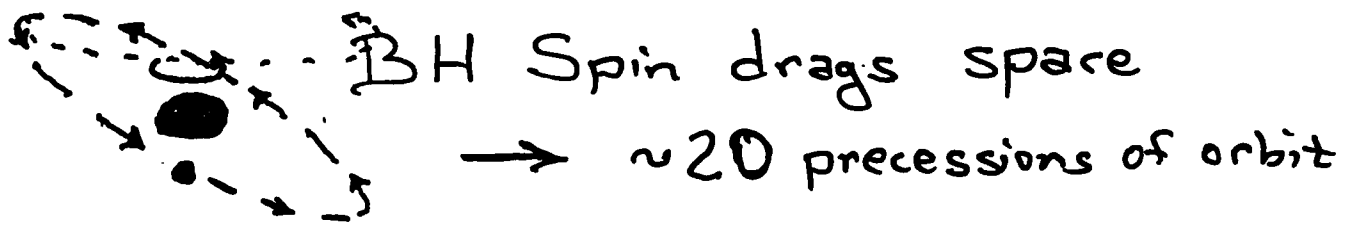
Direction in ring



- LIGO + VIRGO
Pisa, Italy

measure both waveforms;
Direction

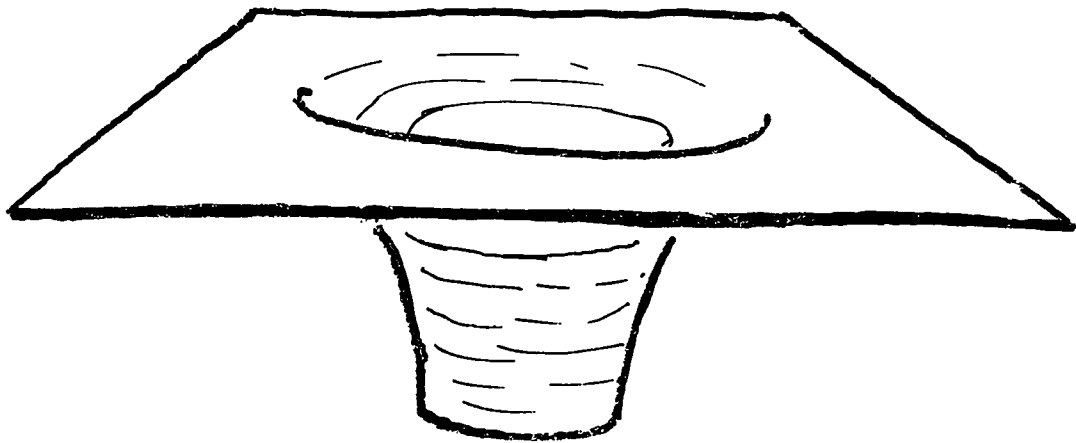
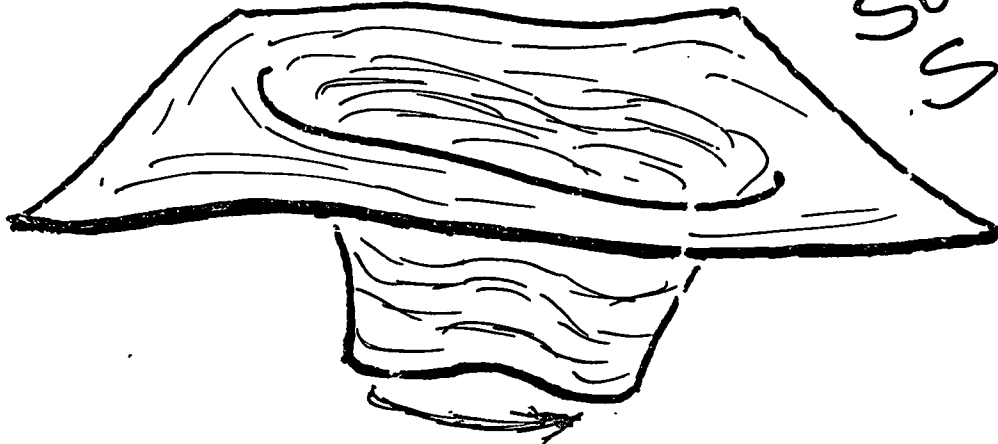
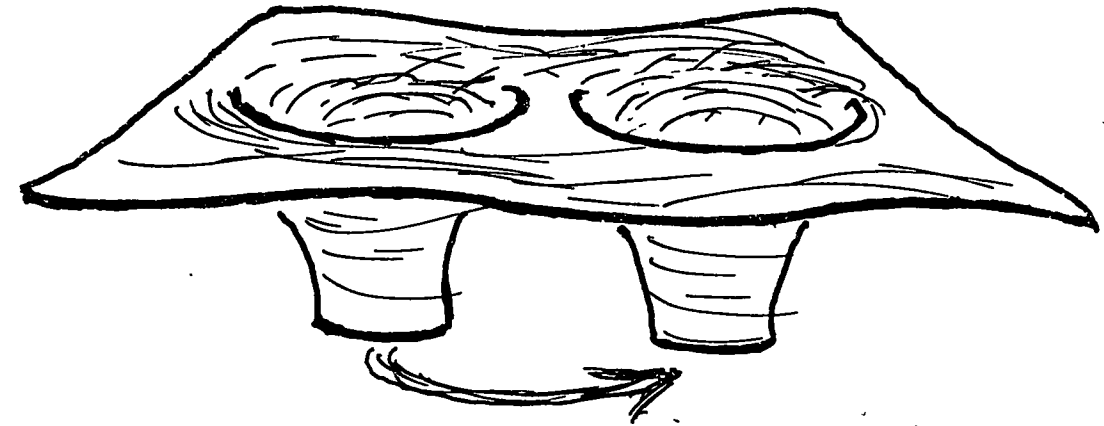




SPECULATION:

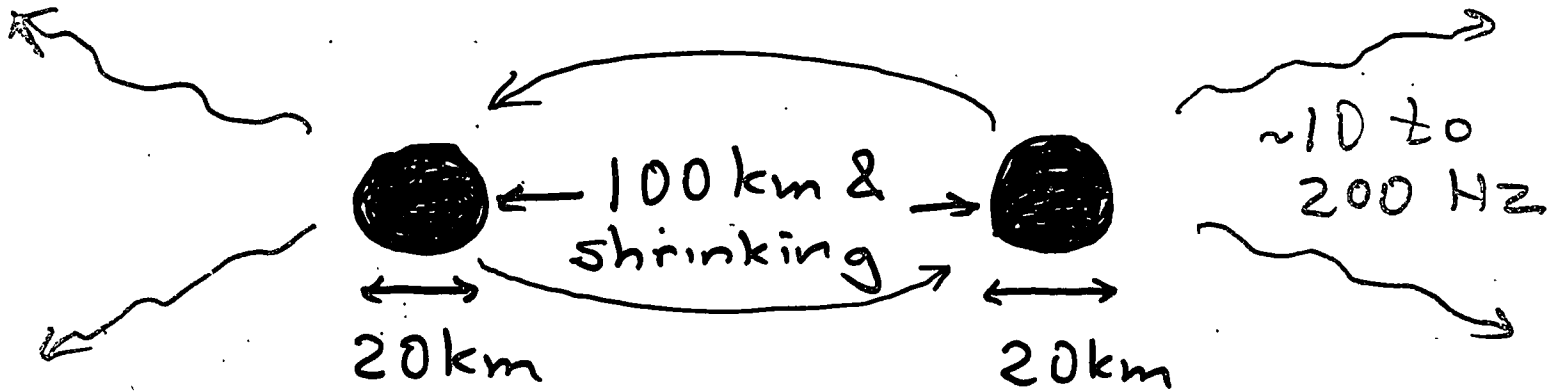
We will "see" objects whose geometry

BLACK HOLES OF COMPARABLE MASS

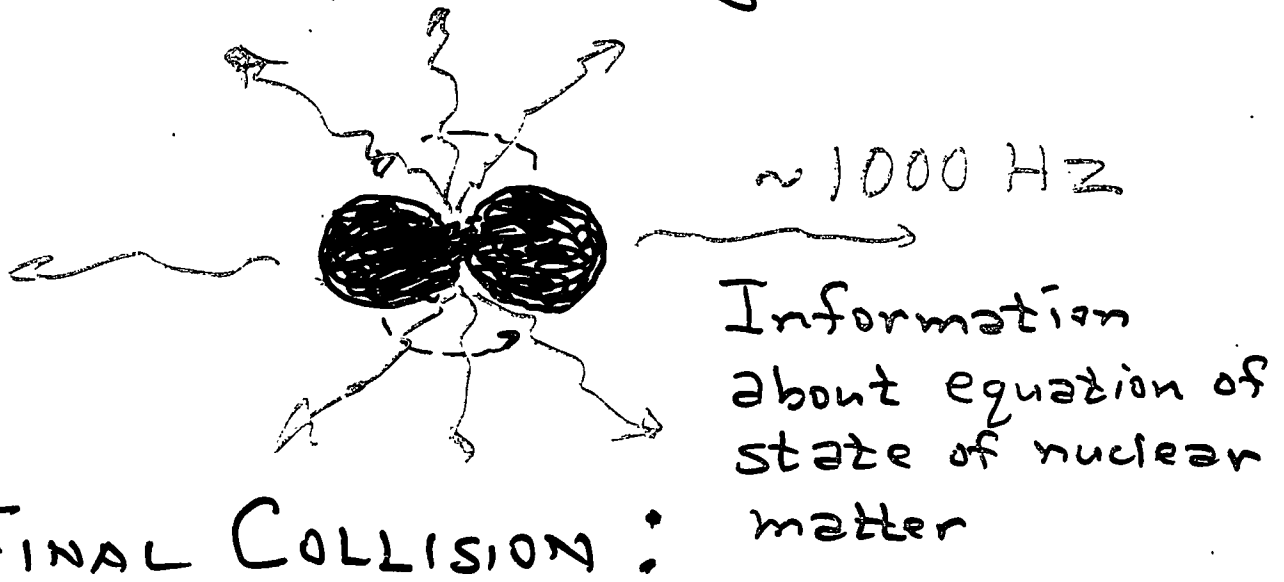


COMPARE
WITH
SUPERCOMPUTE
SIMULATIONS

NEUTRON STAR COALESCENCE



LIGO's "workhorse" broad-band interferometers measure masses and spins during inspiral



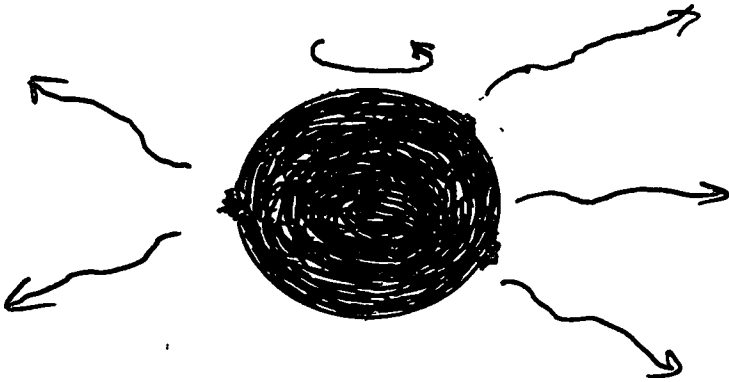
FINAL COLLISION :

Requires special, high-frequency interferometers (in same vacuum system with "workhorse")

[possible after future upgrade]

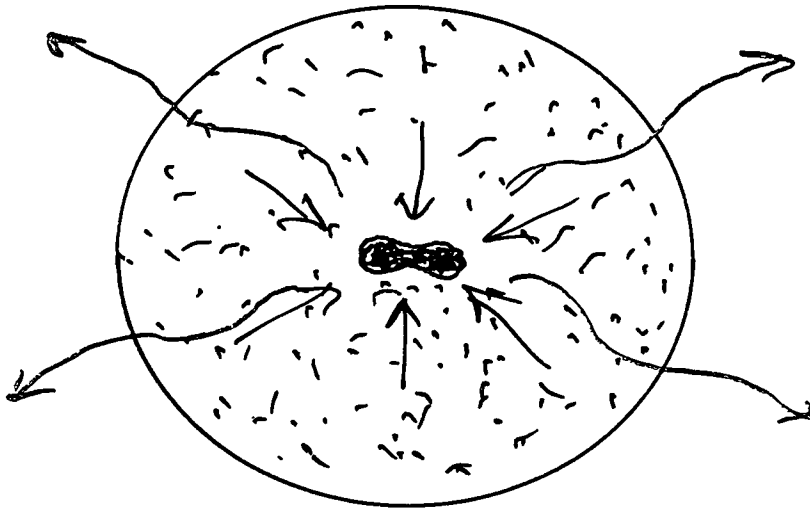
OTHER POSSIBLE SOURCES

SPINNING, "MOUNTAINOUS" NEUTRON STAR

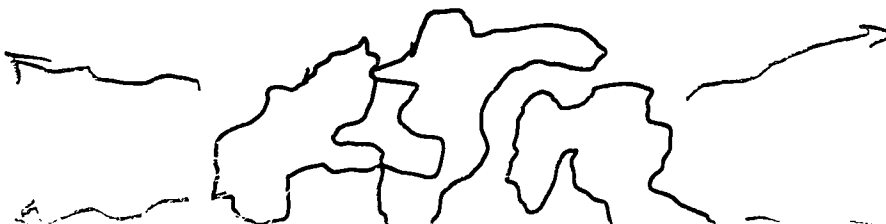


IMPLOSION OF A STAR'S CORE

— WHICH TRIGGERS A SUPERNOVA



VIBRATING LOOPS OF COSMIC STRING



THE BIG BANG SINGULARITY

