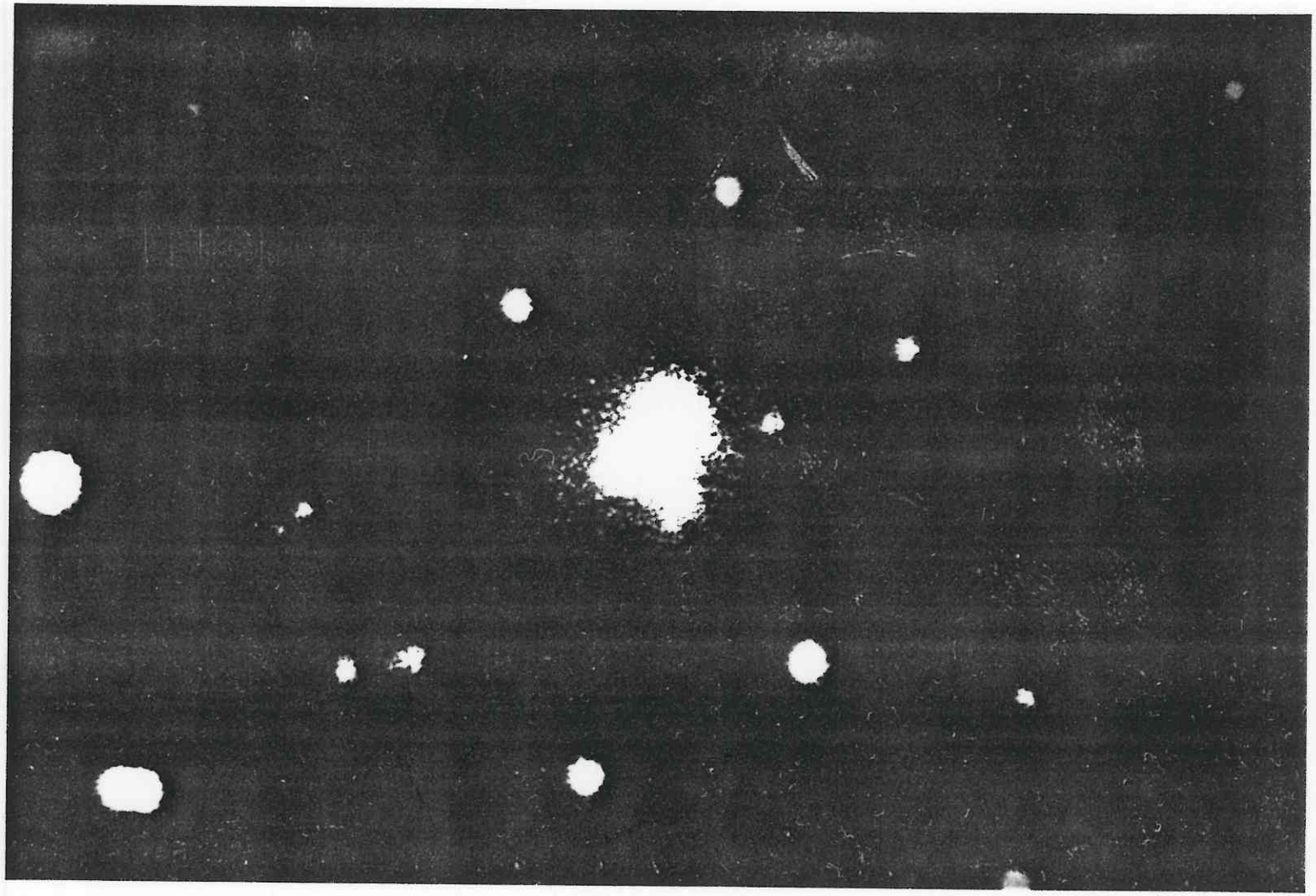
Viewgraphs

Public Lecture in New Mexico

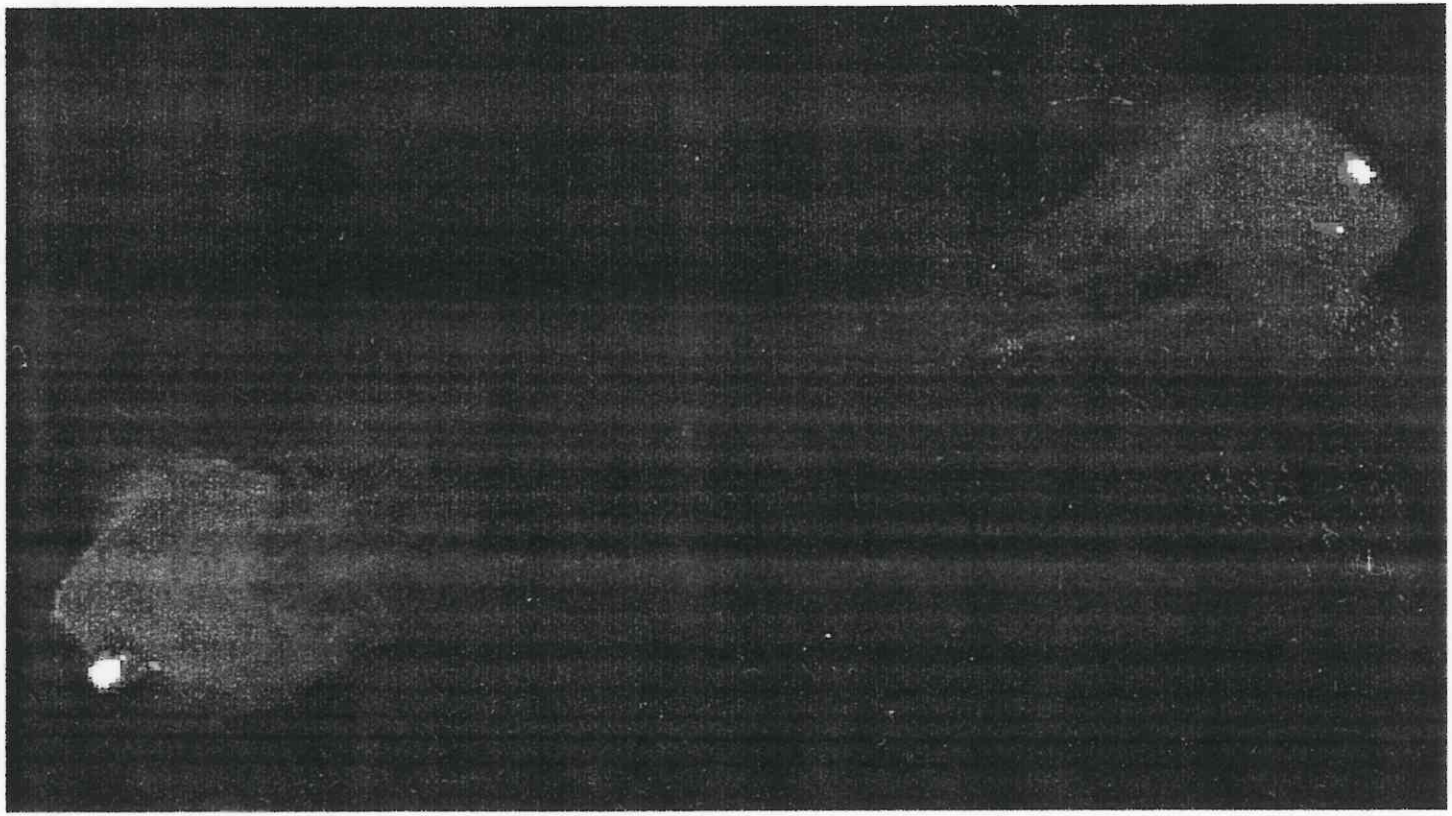
29 February 1996

Stan Whitcomb

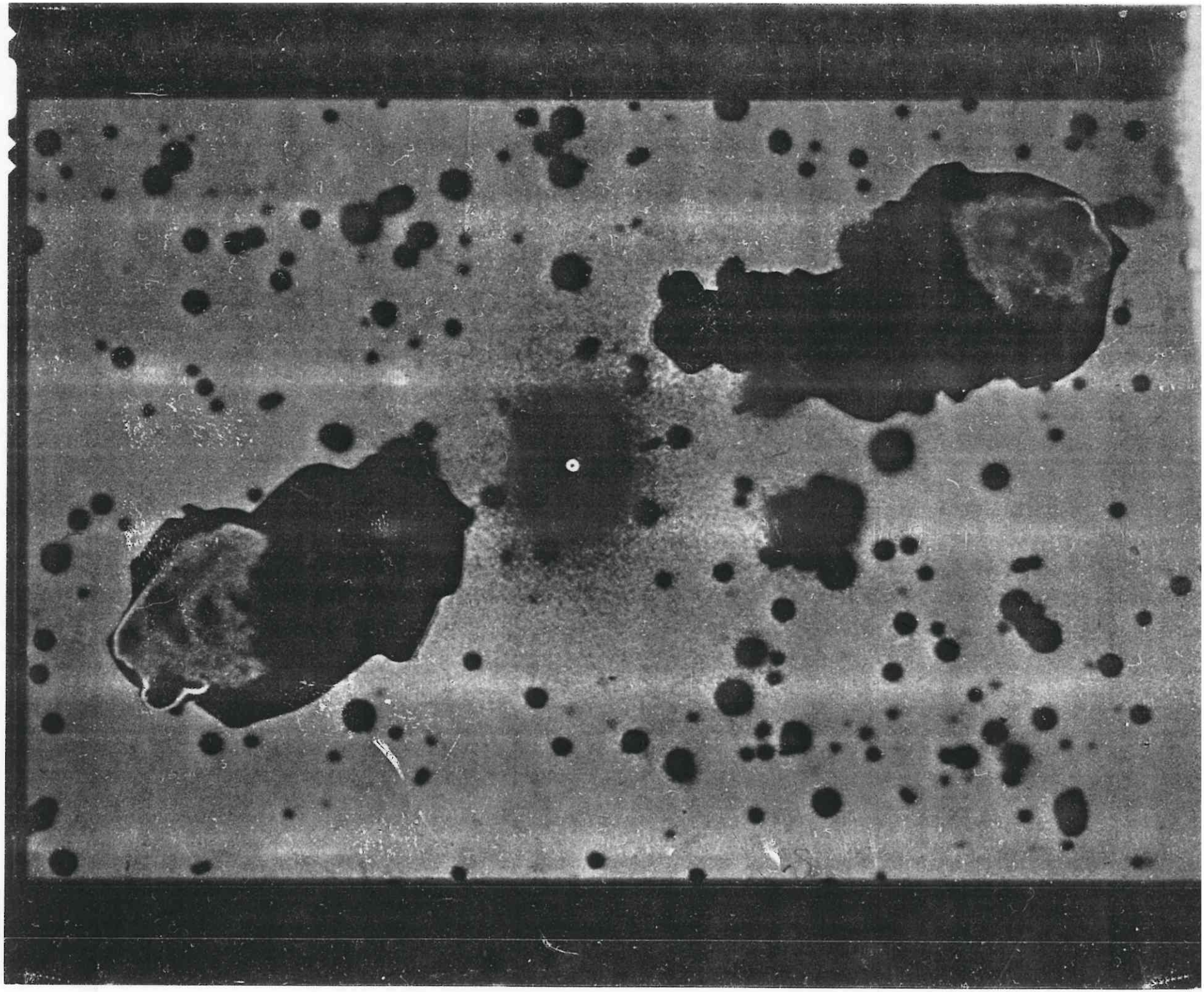
LIGO-G960036



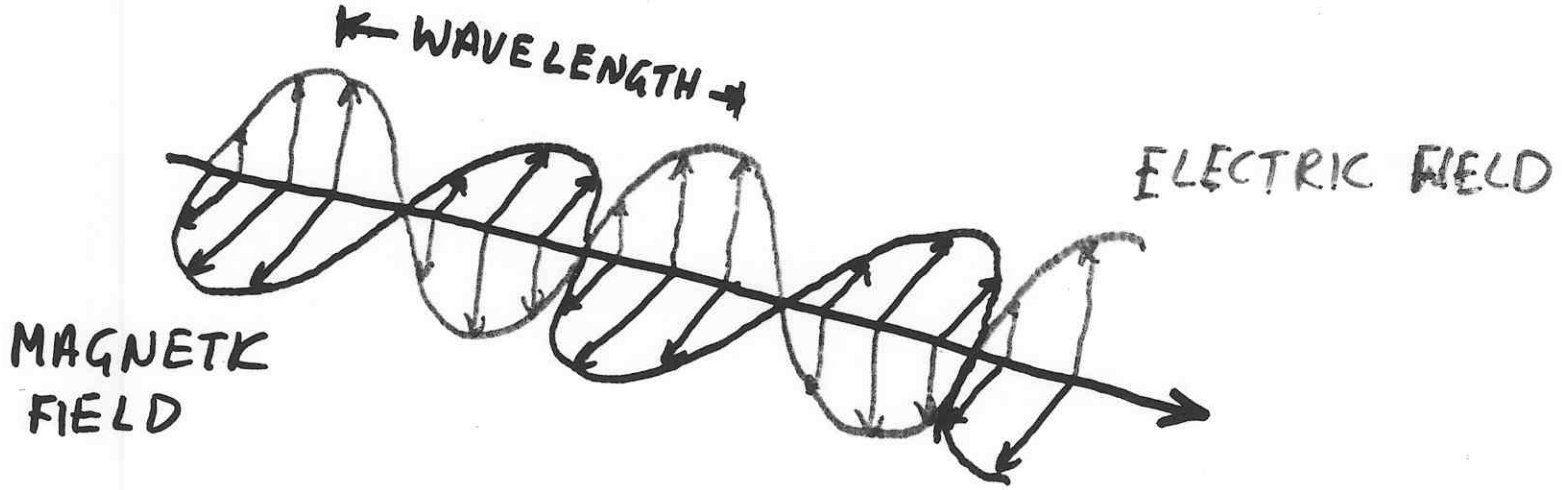
CYGNUS A VIEWED WITH RADIO WAVES



VLA data courtesy of the National Radio Astronomy Observatory, operated by Associated Universities, Inc., under cooperative agreement with the National Science Foundation

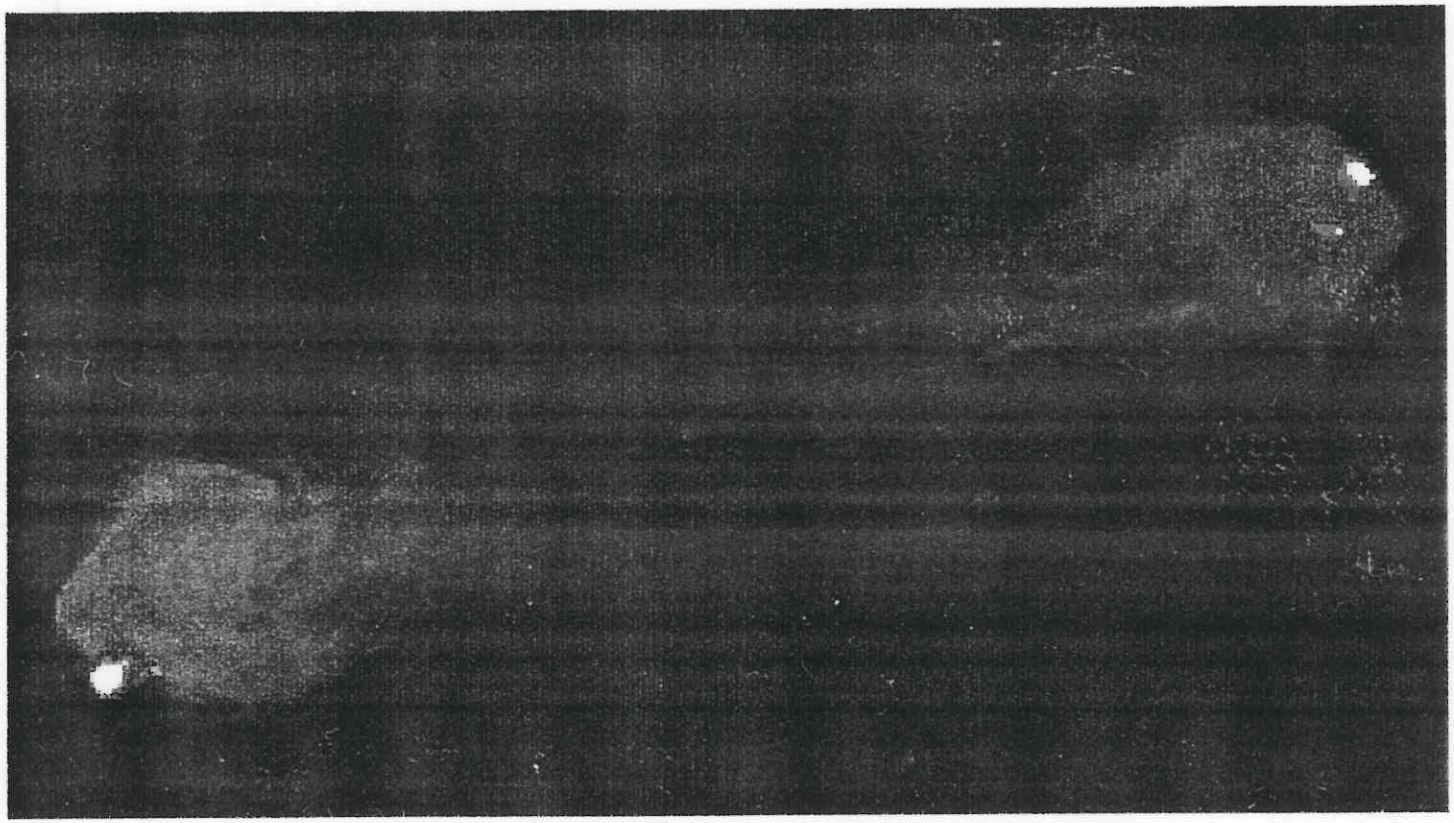


LIGHT AND RADIO WAVES ARE ELECTROMAGNETIC WAVES



- DIFFERENCE BETWEEN LIGHT AND RADIO WAVES IS THEIR WAVELENGTH
  - RADIO WAVELENGTHS RANGE FROM A FEW MILLIMETERS TO 10'S OF METERS
  - THE WAVELENGTH OF LIGHT IS ABOUT 1/2 MICRON (ONE MILLIONTH OF A METER)
- GRAVITATIONAL WAVES ARE A TOTALLY DIFFERENT TYPE OF WAVE!

CYGNUS A VIEWED WITH RADIO WAVES

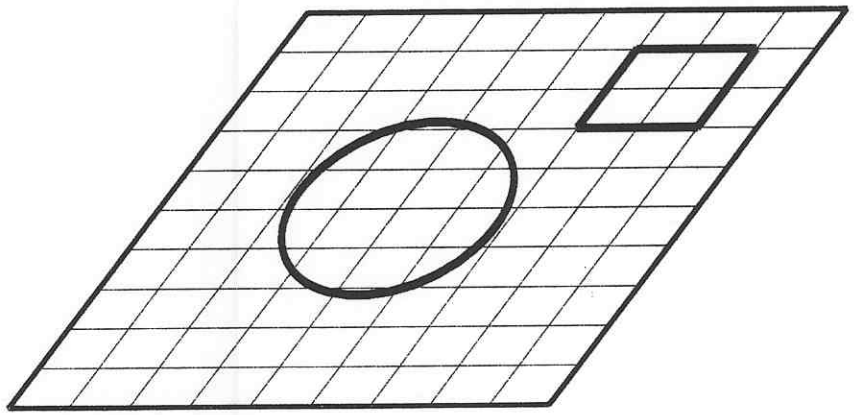


VLA data courtesy of the National Radio Astronomy Observatory, operated by Associated Universities, Inc., under cooperative agreement with the National Science Foundation

GENERAL RELATIVITY AS A THEORY OF GRAVITY

- **ISAAC NEWTON (1687)**
  - SPACE IS ABSOLUTE, GOVERNED BY THE RULES OF EUCLIDEAN GEOMETRY
  - TIME MARCHES FORWARD THE SAME FOR ALL OBSERVERS
  - GRAVITY IS A FORCE THAT ATTRACTS ALL MASSIVE BODIES TOWARD EACH OTHER
- **ALBERT EINSTEIN (1913-16)**
  - SPACE AND TIME ARE NOT THE SAME FOR ALL OBSERVERS
  - SPACE AND TIME ARE INTIMATELY RELATED -- DIFFERENT ASPECTS OF CONCEPT THAT PHYSICISTS CALL SPACETIME
  - GRAVITY CAN BE DESCRIBED AS DEVIATIONS OF SPACETIME FROM OUR FAMILIAR EUCLIDEAN GEOMETRY, WHICH PHYSICISTS CALL CURVATURE
  - THESE DISTORTIONS OF SPACETIME ARE NOT STATIC, BUT CAN EXIST IN THE FORM OF WAVES WHICH TRAVEL AT THE SPEED OF LIGHT

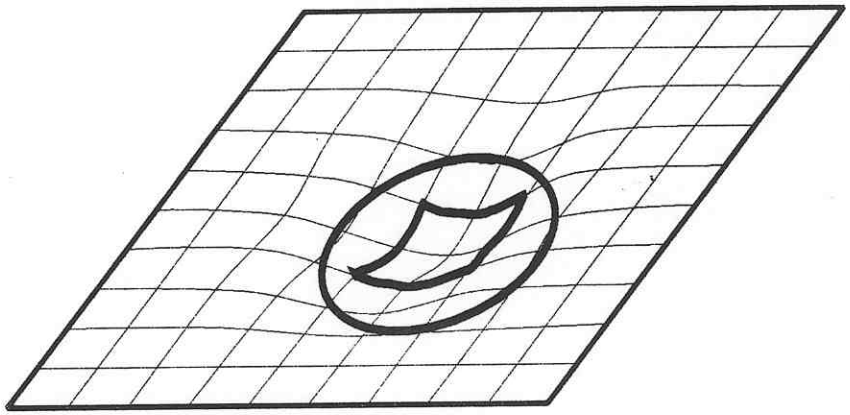
FLAT VERSUS CURVED SPACETIME



FLAT SPACETIME

$C = \pi D$

Σ ANGLES $= 360^\circ$



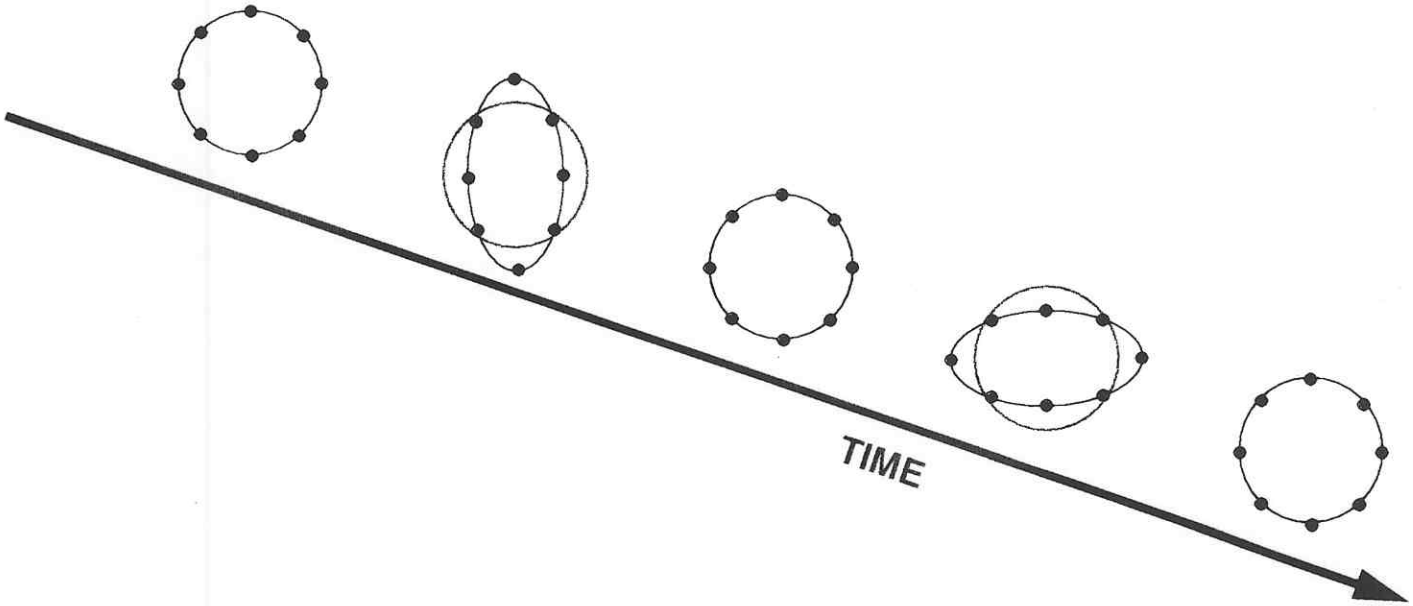
CURVED SPACETIME

$C < \pi D$

Σ ANGLES $< 360^\circ$

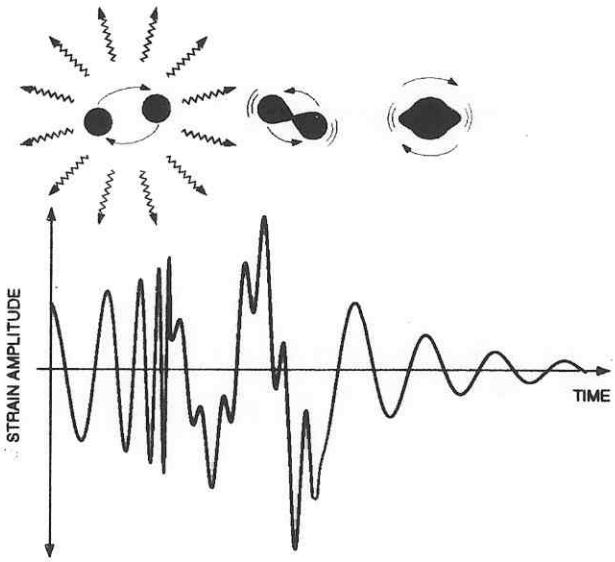
GRAVITATIONAL WAVE (GW) EFFECTS

- GWs CAUSE GEOMETRY/LENGTH FLUCTUATIONS
- TRANSVERSE, QUADRUPOLAR WAVES
  - x and + POLARIZATIONS
- DIMENSIONLESS AMPLITUDE, STRAIN $h = \Delta L/L \sim 10^{-21}$
  - $\sim \frac{\text{ATOMIC DIAMETER}}{\text{EARTH-SUN DISTANCE}} \approx \frac{1 \text{ Angstrom}}{150 \text{ Gm}}$

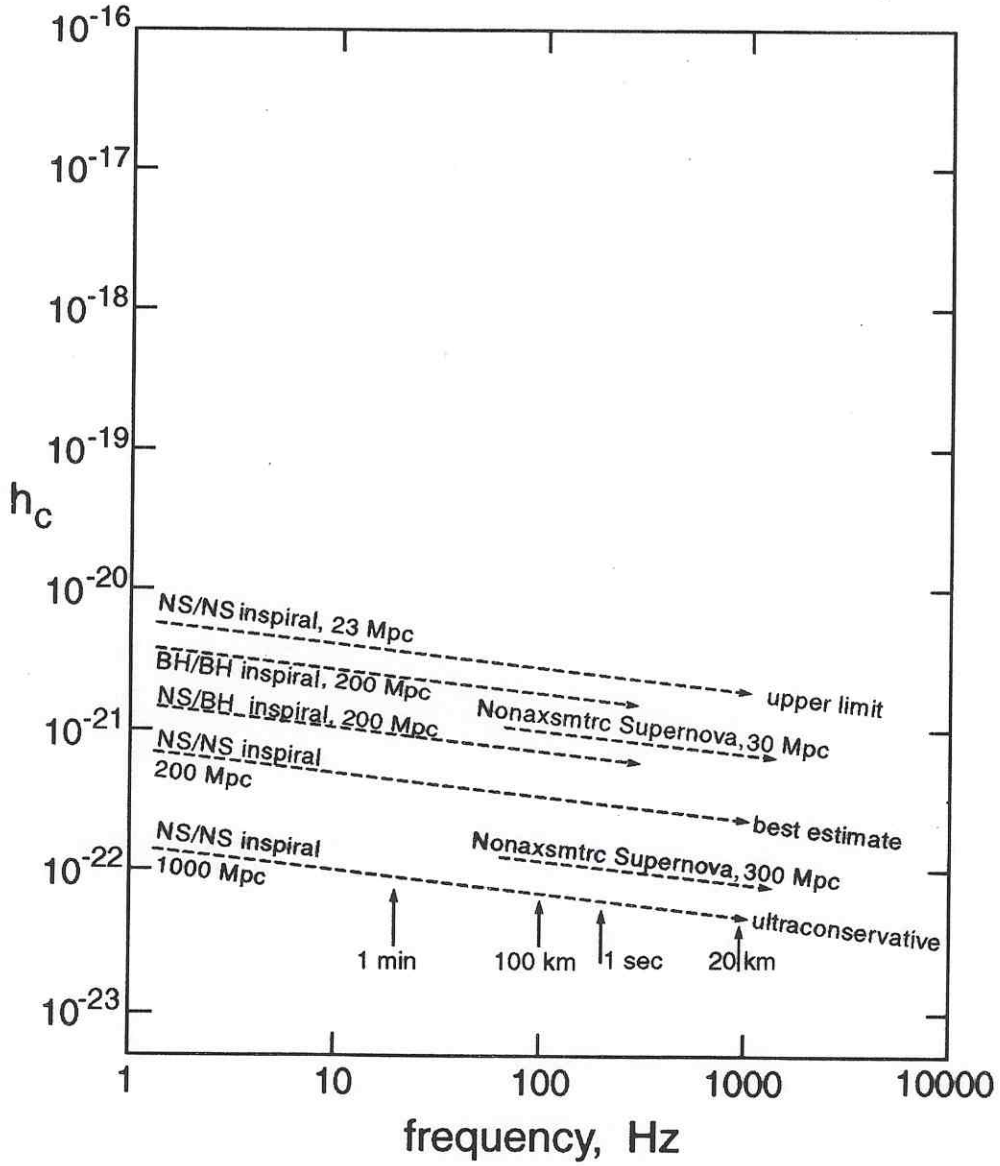


GW SOURCES

- **COMPACT BINARY COALESCENCE**
  - NEUTRON STAR (NS)
  - BLACK HOLE (BH)
  - SIGNALS RANGE FROM 10 Hz TO 1000 Hz
  - SHORT DURATION (~ 1 MINUTE)
- **SUPERNOVA**
  - ASYMMETRIC COLLAPSE OF STELLAR CORE TO FORM NEUTRON STAR
  - VERY SHORT DURATION (~ millisecond)
- **COSMIC BACKGROUND**
  - GW ANALOG TO THE COSMIC MICROWAVE ("3 Degree") BACKGROUND
  - EXTREMELY WEAK SIGNAL



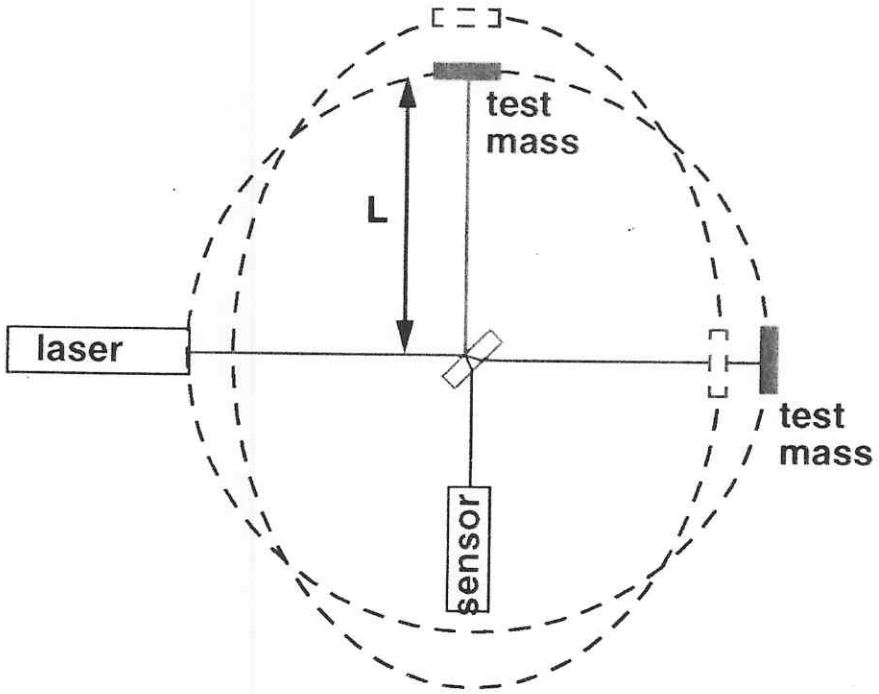
ESTIMATED STRENGTH OF GW SOURCES



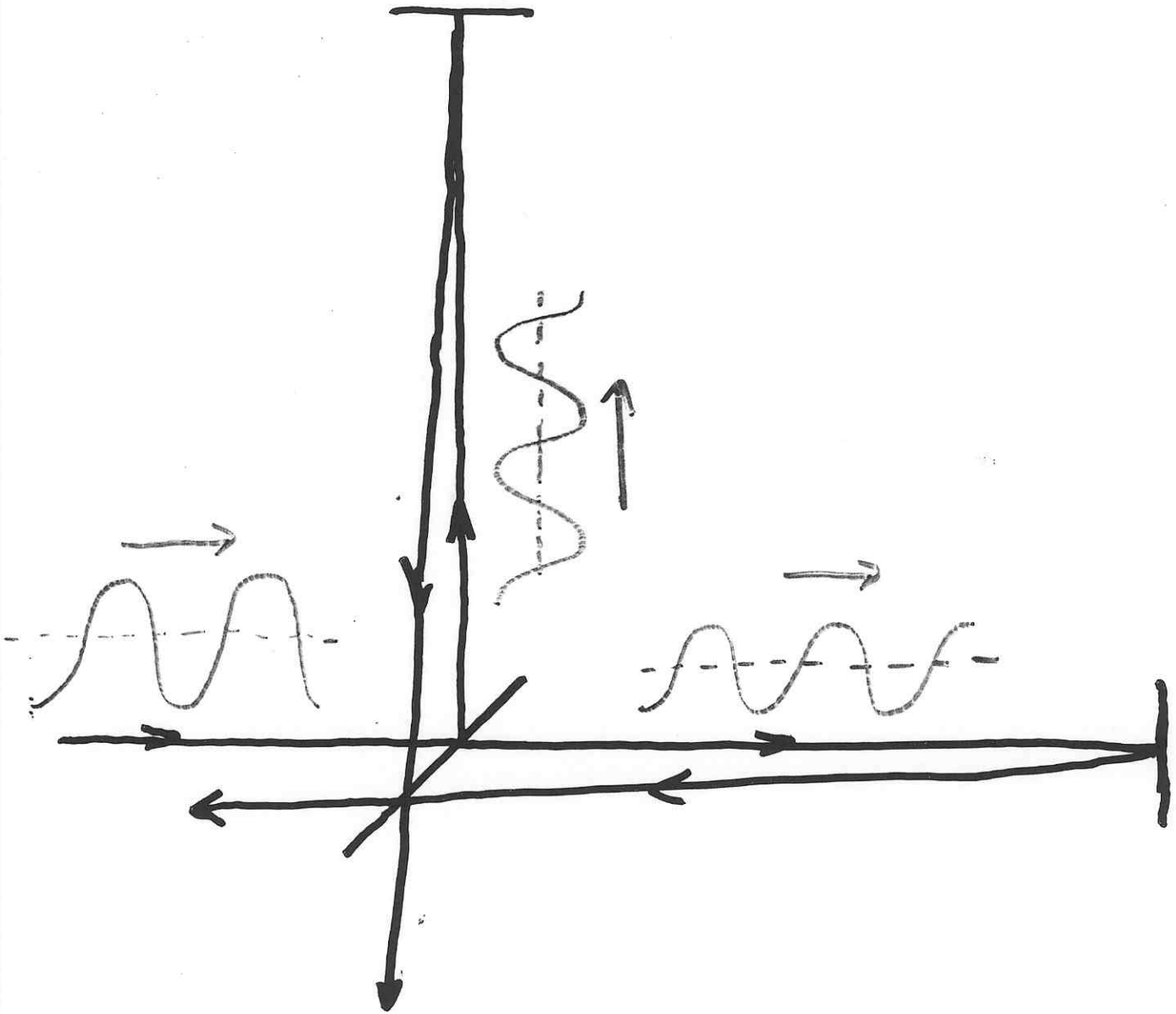
GW OPTICAL DETECTION

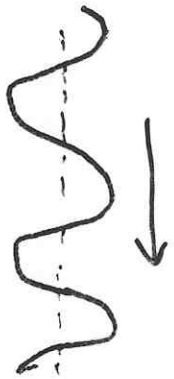
- **MICHELSON INTERFEROMETER**
  - QUADRUPOLAR GW →
  - LASER FREQUENCY FLUCTUATIONS →
  - MINUTE STRAIN →
  →

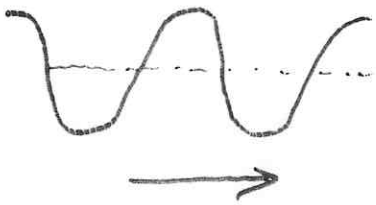
TWO ORTHOGONAL ARMS

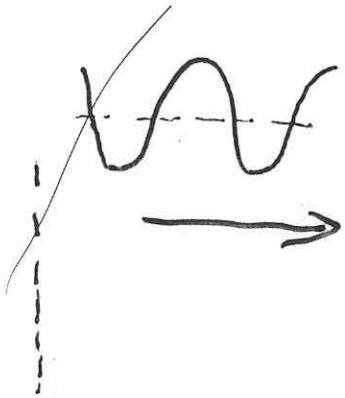


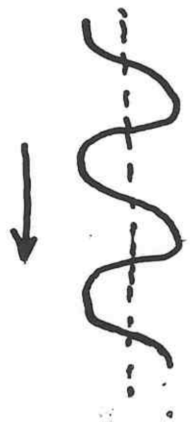
How Does an Interferometer Work?

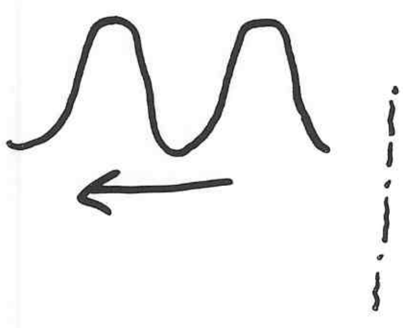


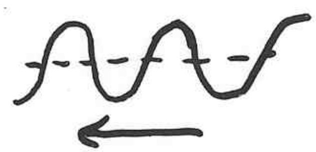






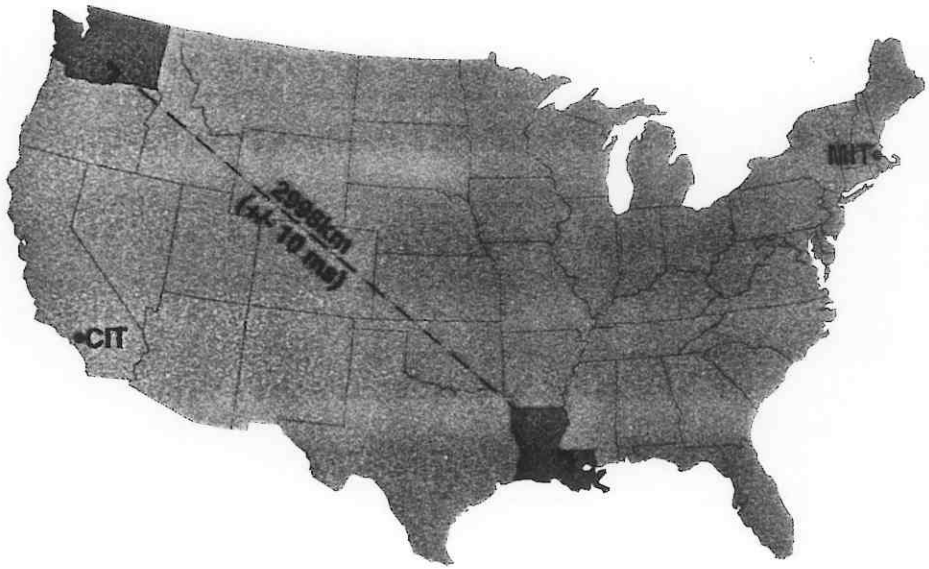


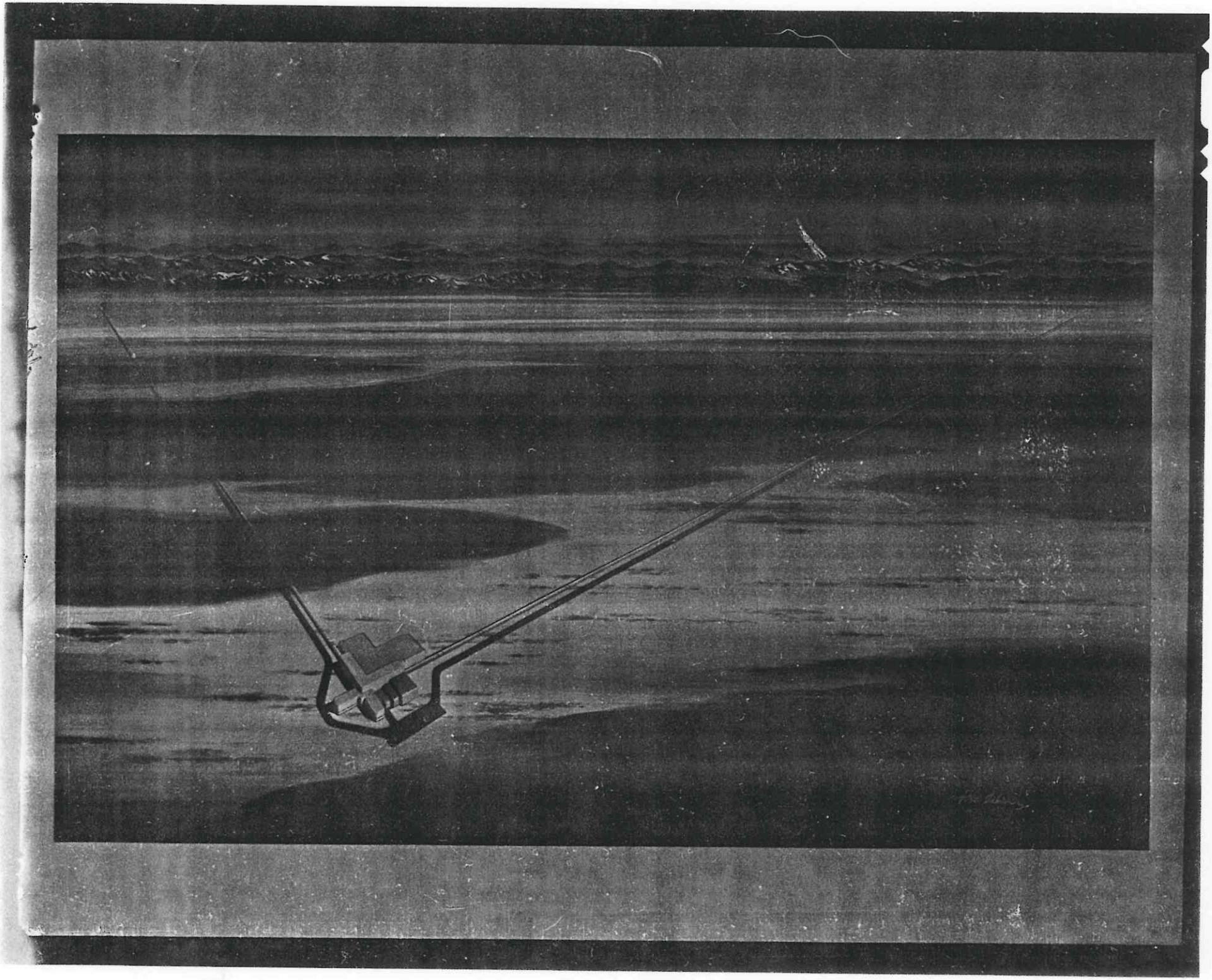


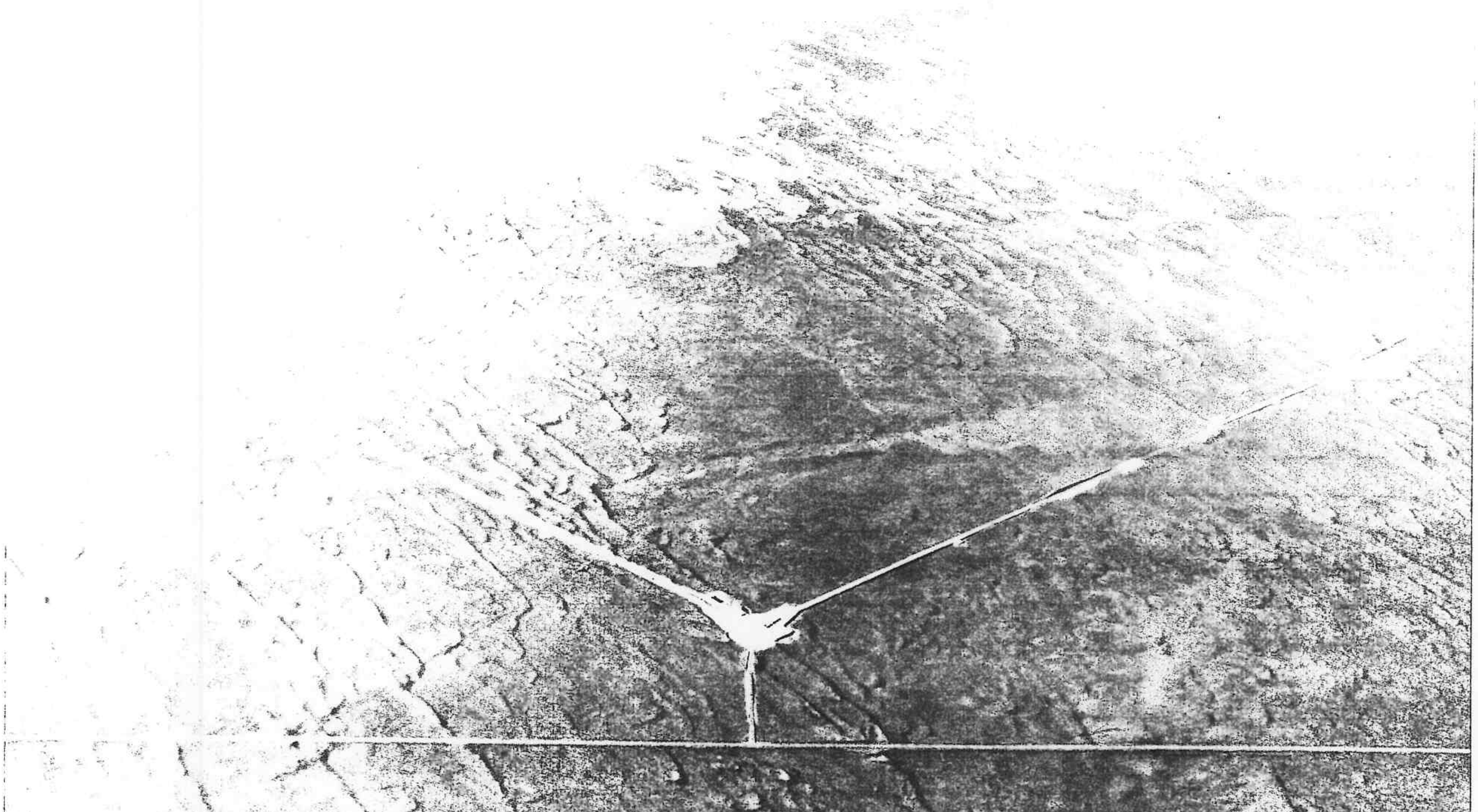


LIGO OVERVIEW

- NATIONAL SCIENCE FOUNDATION (NSF) PROJECT BEING DEVELOPED JOINTLY BY:
  - CALIFORNIA INSTITUTE OF TECHNOLOGY
  - MASSACHUSETTS INSTITUTE OF TECHNOLOGY
- GOALS:
  - DIRECT DETECTION OF GRAVITATIONAL WAVES (GW)
  - OPEN NEW WINDOW ON THE UNIVERSE
- REQUIRE COINCIDENCE BETWEEN TWO WIDELY-SEPARATED SITES TO ELIMINATE LOCAL DISTURBANCES



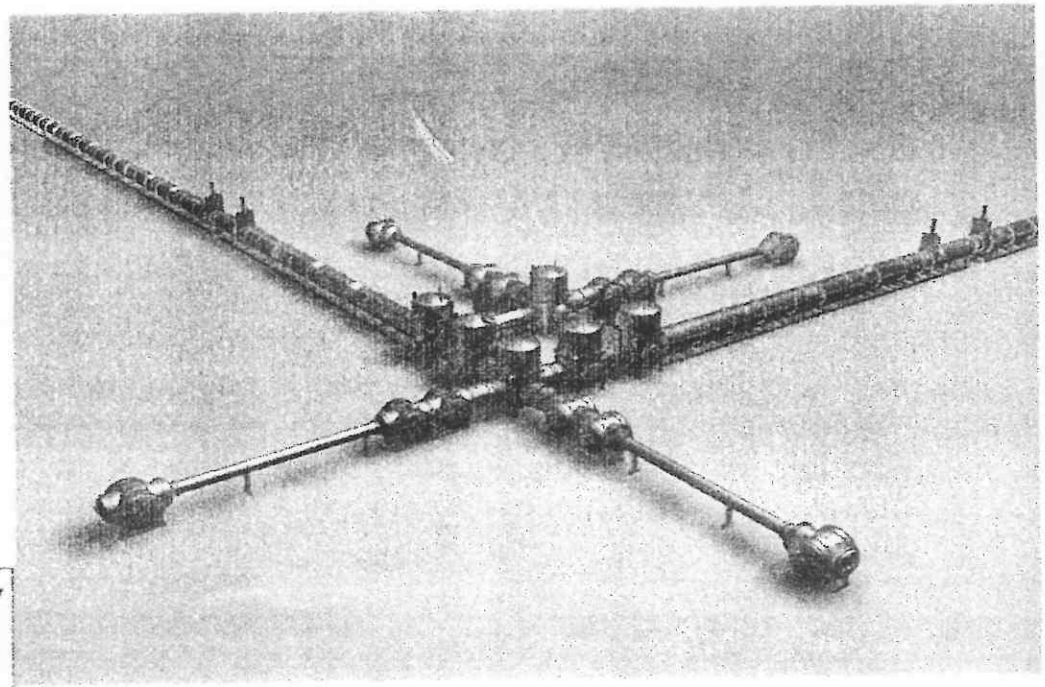


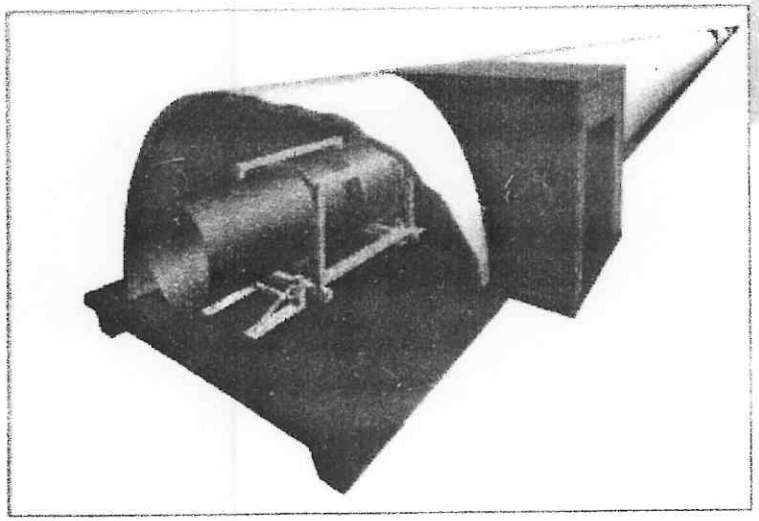


VACUUM EQUIPMENT & BEAM TUBE

- ONE OF THE LARGEST VACUUM SYSTEMS IN THE WORLD

- EXTENSIVE NETWORK OF VACUUM CHAMBERS TO HOUSE SENSITVE INTERFEROMETER COMPONENT

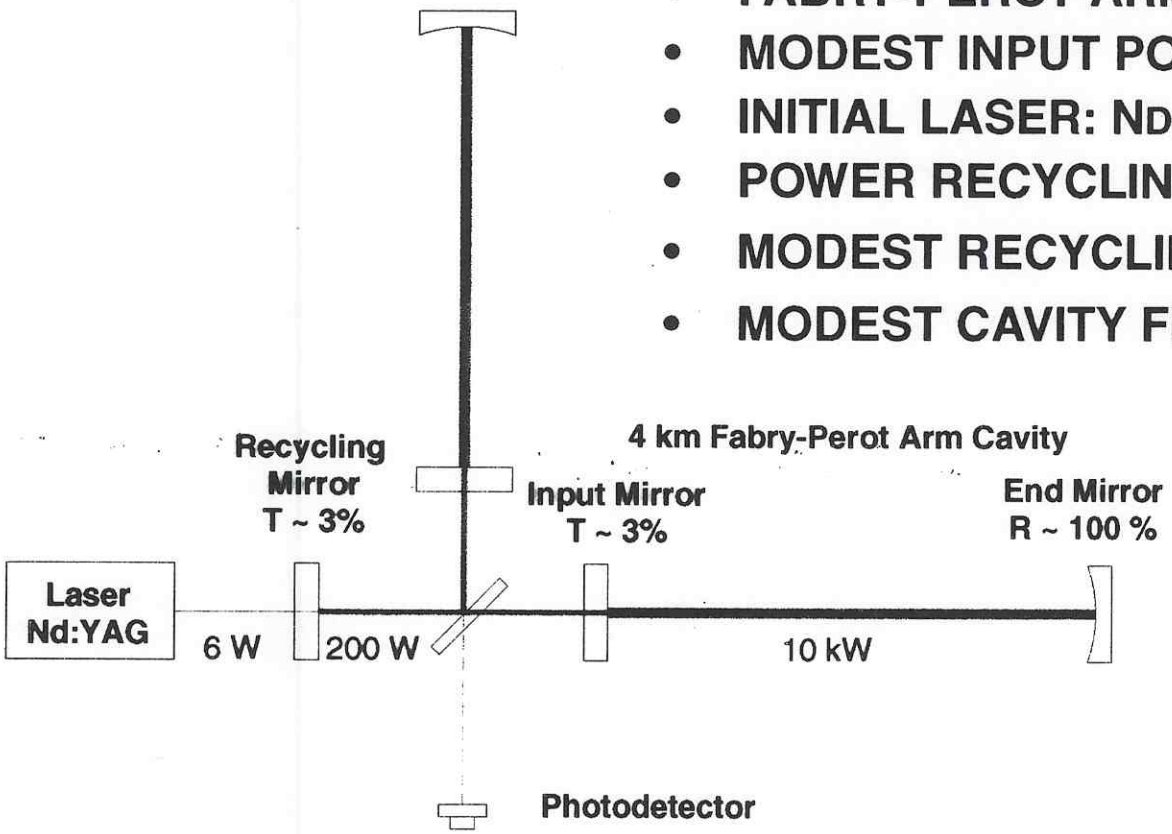




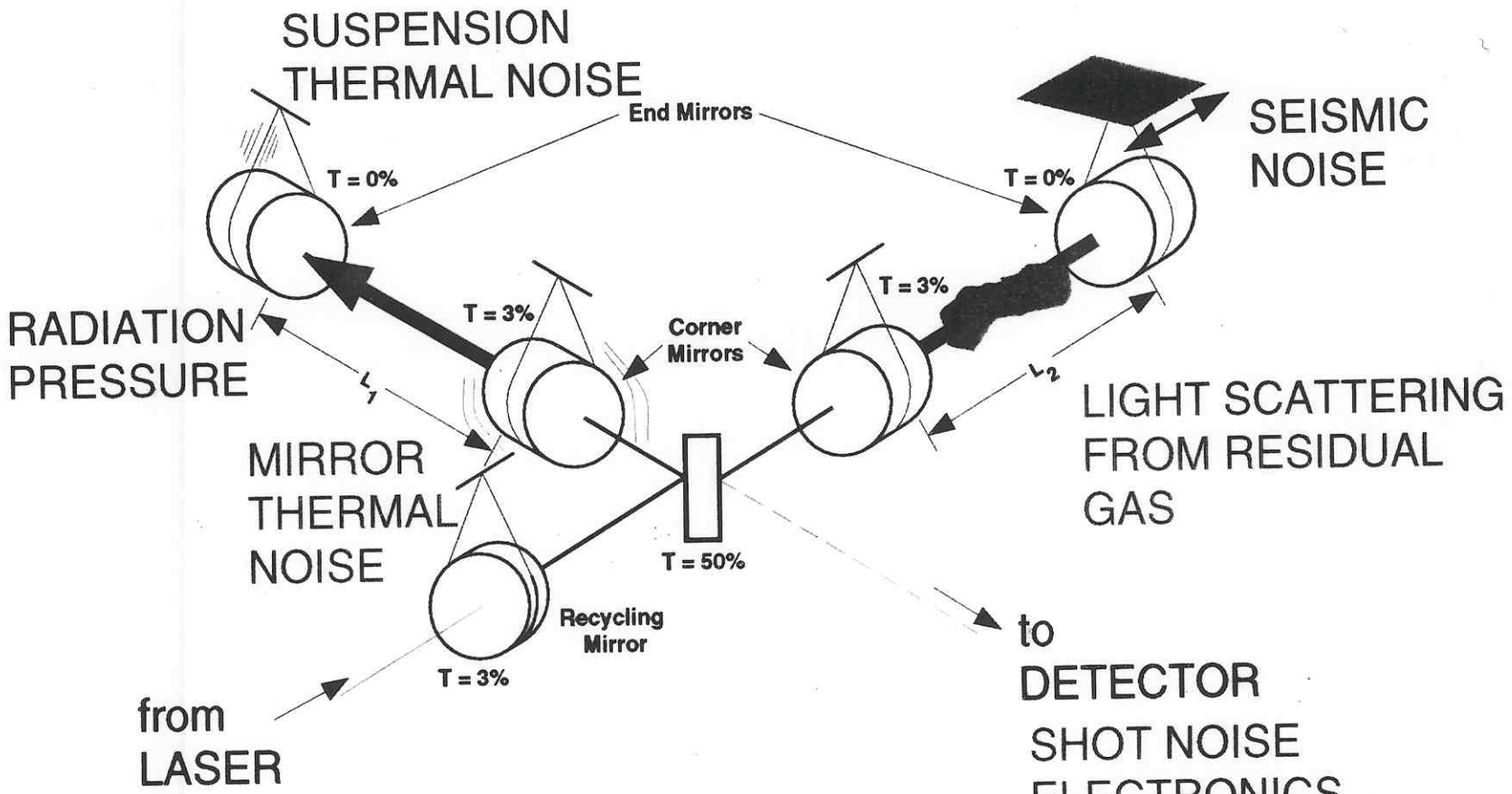
- HIGH VACUUM BEAM TUBES TO CARRY LASER BEAMS DOWN UP AND DOWN ARMS

INITIAL INTERFEROMETER CONFIGURATION

- FABRY-PEROT ARM CAVITIES
- MODEST INPUT POWER (6 w)
- INITIAL LASER: ND:YAG $\lambda = 1.06\ \mu m$
- POWER RECYCLING
- MODEST RECYCLING FACTOR ($\mathcal{R} \sim 30X$)
- MODEST CAVITY FINESSE ($\mathcal{F} \sim 50$)



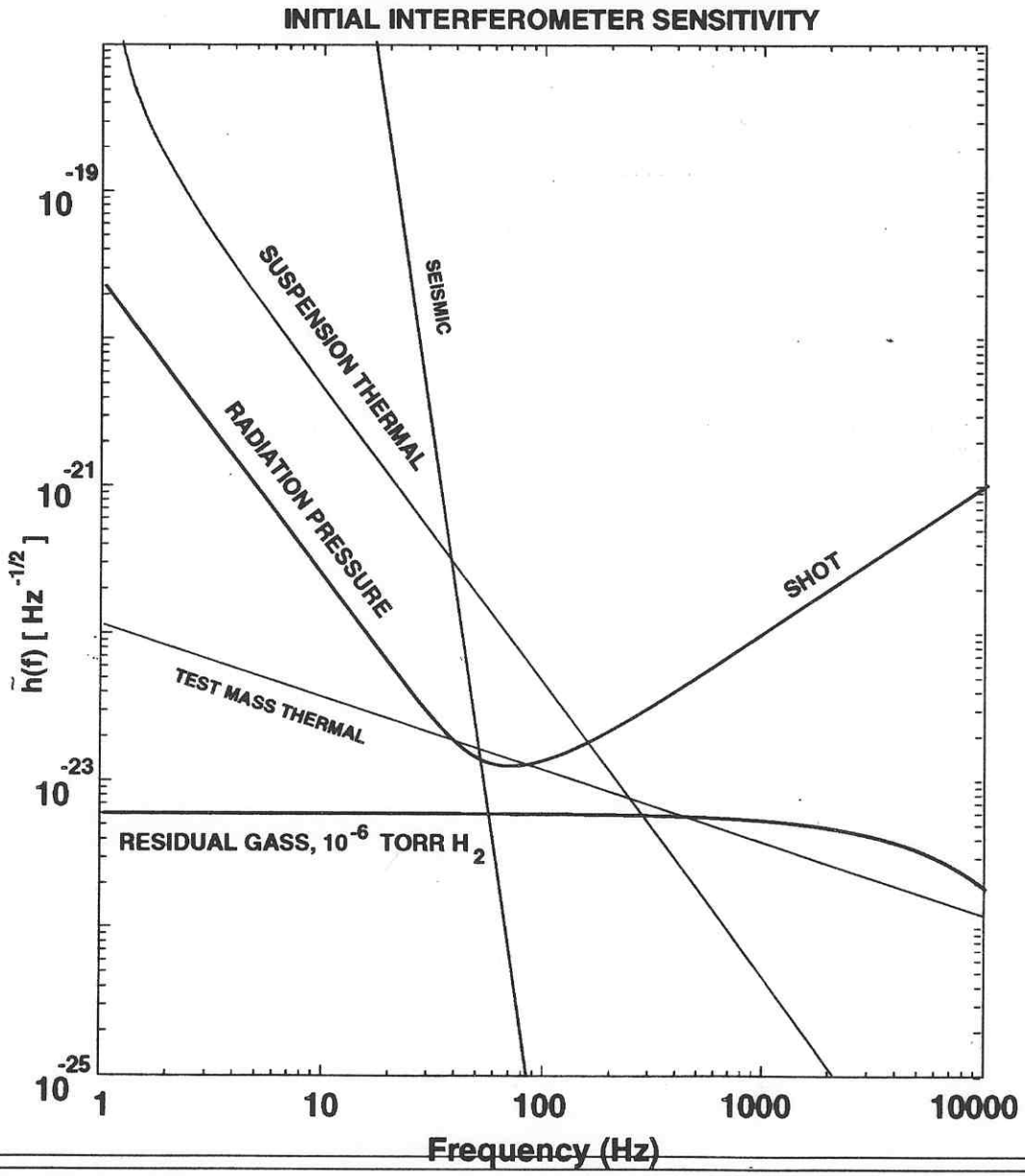
NOISE SOURCES



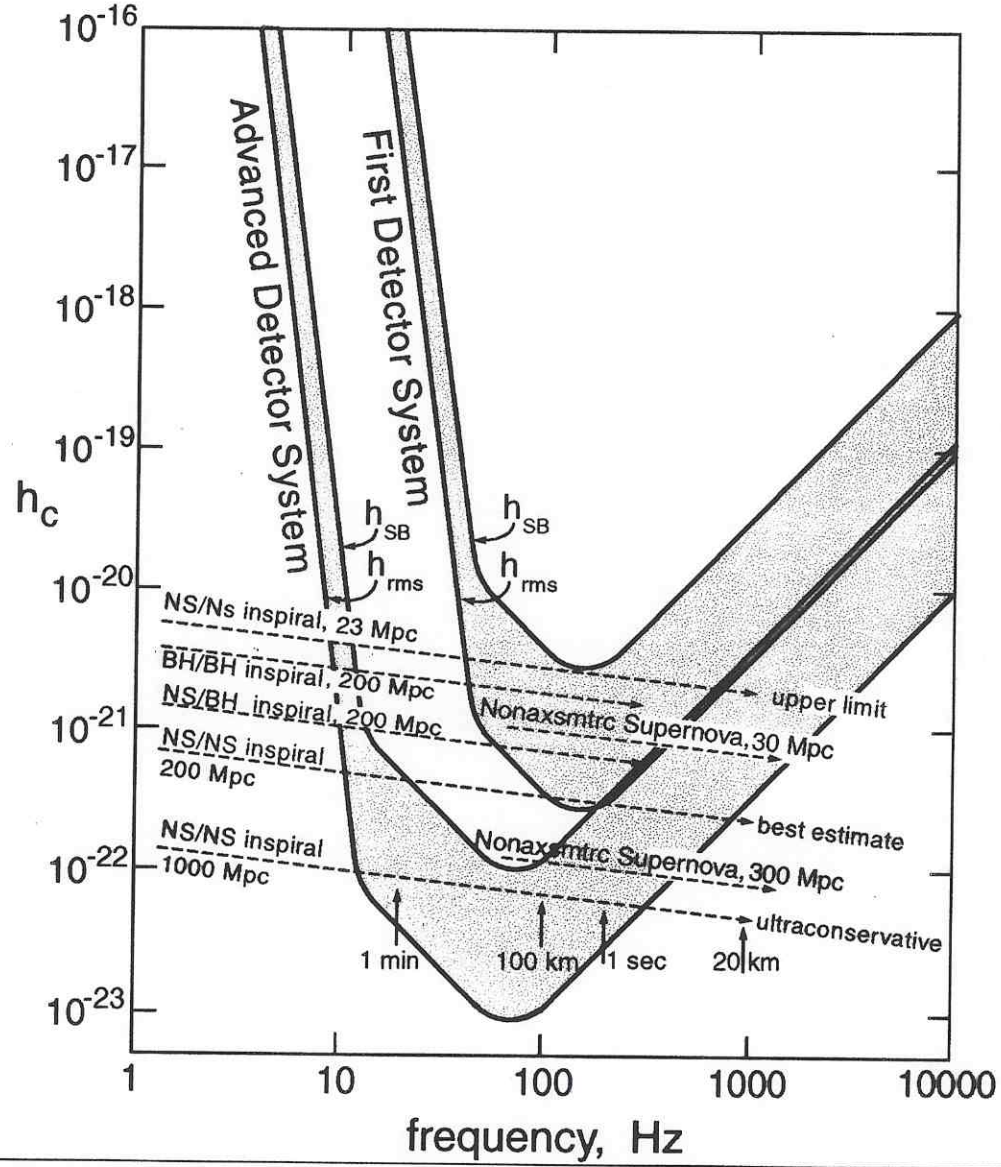
INITIAL LIMITS TO SENSITIVITY

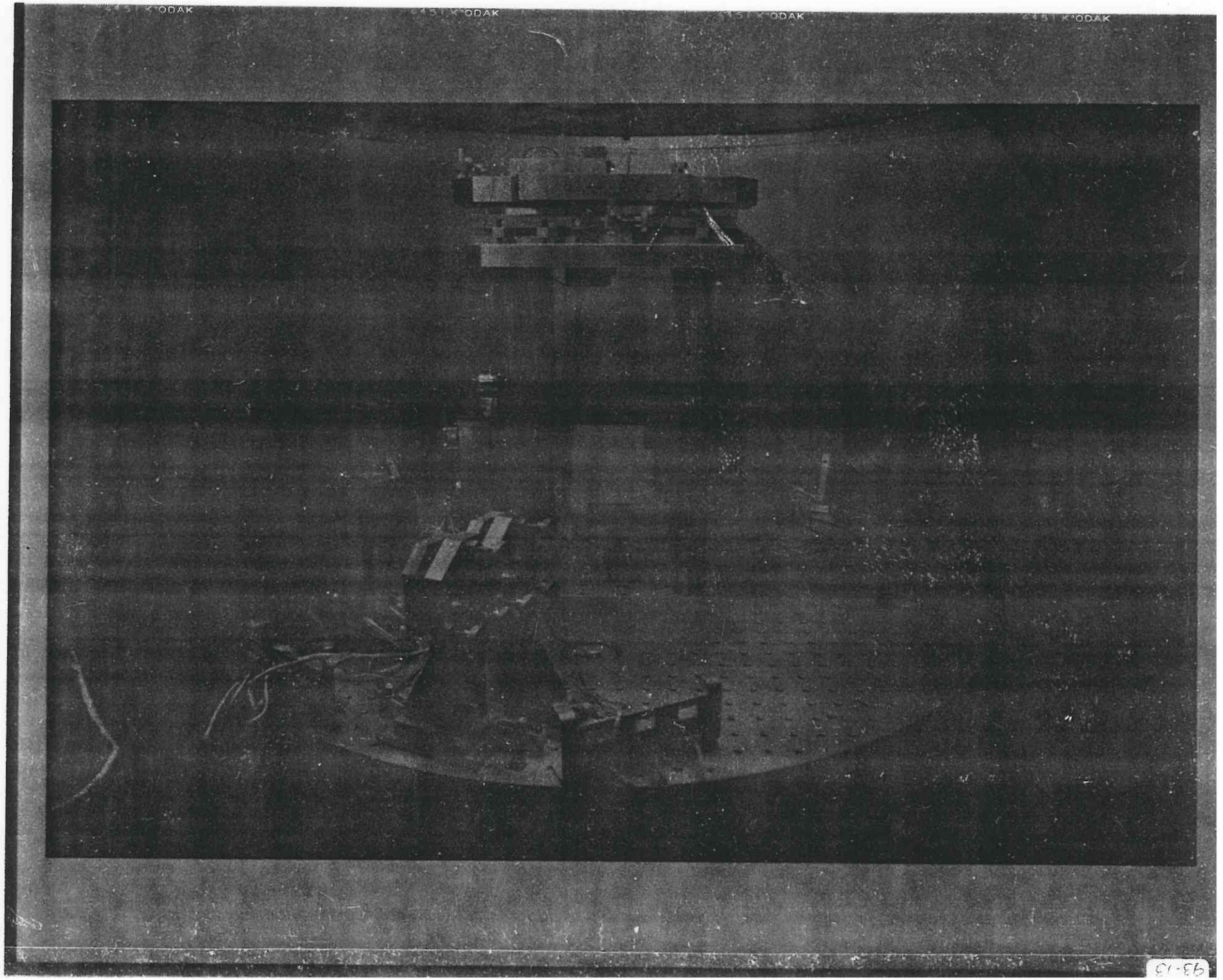
- DISPLACEMENT NOISE (PHYSICAL MOTION)
  - SEISMIC NOISE
    - SEISMICALY QUIET SITES
    - MULTI-STAGE SEISMIC ISOLATION SYSTEM & PENDULUM SUSPENSIONS FOR THE TEST MASSES
  - THERMAL NOISE
    - THERMAL NOISE DUE TO PENDULUM MODE
    - THERMAL NOISE DUE TO INTERNAL VIBRATIONAL MODES
    - CAREFUL MECHANICAL DESIGN TO ENSURE NO MECHANICAL MODES AT LIGO FREQUENCIES
- SENSING NOISE
  - SHOT NOISE
    - HIGH POWER STABILIZED LASER
    - NEARLY PERFECT OPTICS TO USE LASER POWER EFFICIENTLY

INITIAL INTERFEROMETER DESIGN PERFORMANCE GOAL

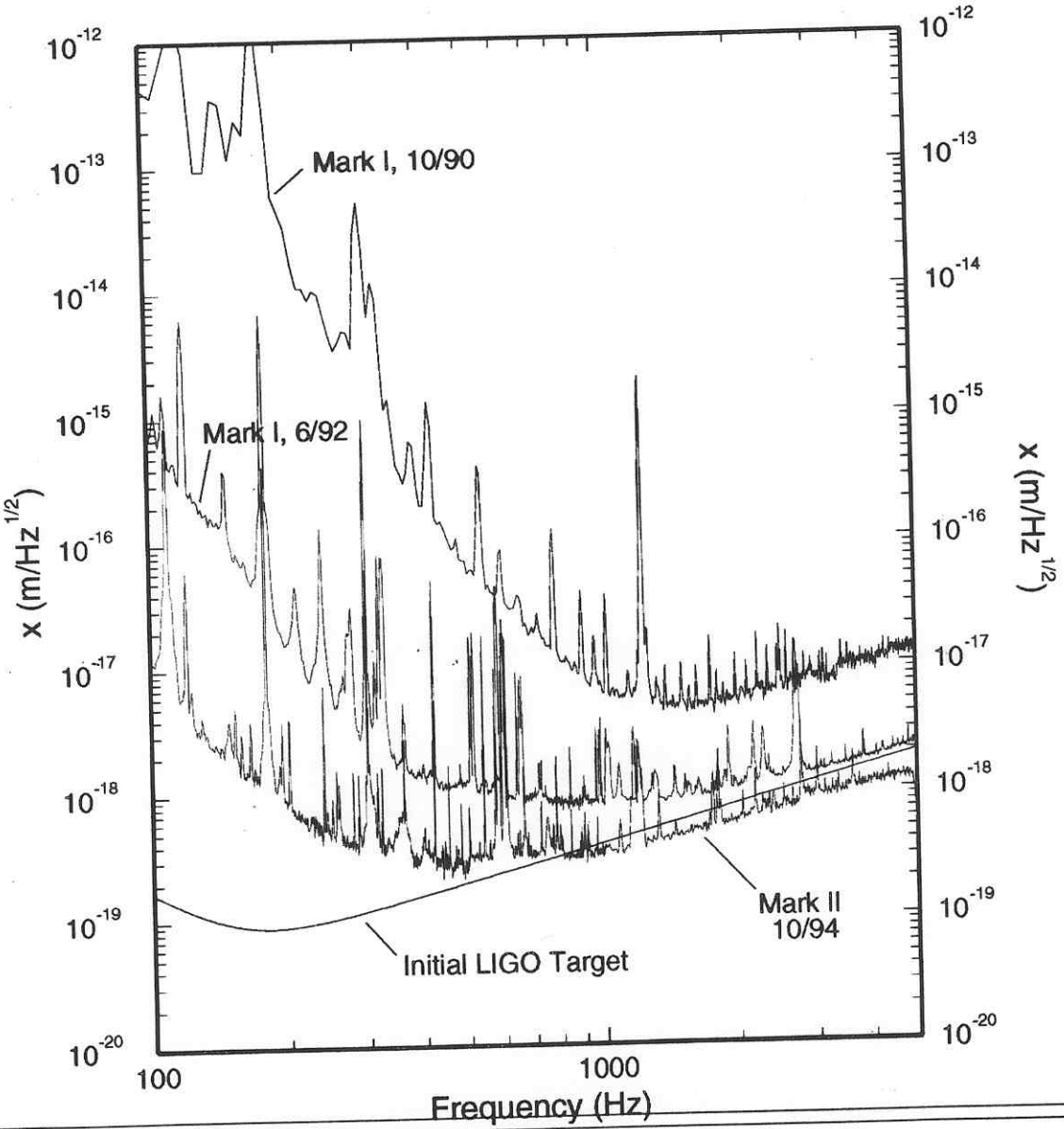


COMPARISON OF LIGO SENSITIVITY GOALS AND ESTIMATED GW SOURCES




KODAK
KODAK
KODAK
KODAK

PROGRESSIVE IMPROVEMENT IN THE 40-METER PROTOTYPE SENSITIVITY



THE FUTURE?

- **LIGO FACILITIES ARE PROCEEDING FROM FINAL DESIGN INTO FABRICATION & CONSTRUCTION**
  - **BUILDINGS AND VACUUM SYSTEM READY IN WASHINGTON: SUMMER 1998**
  - **BUILDINGS AND VACUUM SYSTEM READY IN LOUISIANA: SPRING 1999**
  - **FIRST COINCIDENCE RUNS WITH DETECTORS: SUMMER 2000**

- **THE QUESTION THAT ALWAYS GETS ASKED:**

  WILL LIGO SEE GRAVITATIONAL WAVES?

THE RIGHT QUESTIONS

- **WHEN WILL LIGO SEE GRAVITATIONAL WAVES?**
- **WHAT NEW AND UNEXPECTED SOURCES OF GRAVITATIONAL WAVES WILL WE SEE?**
- **HOW WILL OUR STUDY OF GRAVITATIONAL WAVES CHANGE OUR UNDERSTANDING OF THE UNIVERSE?**