

XI. GRAVITATION RESEARCH*

Academic and Research Staff

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RESEARCH OBJECTIVES

Research in this group is concerned with an experimental investigation of gravitational interaction. Present emphasis is directed toward the experimental consequences of a scalar gravitational interaction, different versions of which have been proposed by Dicke, Jordon, and Nordstrom. In these theories the local value of G , the Newtonian gravitational "constant," can be interpreted as the scalar field variable that becomes a function of the mass distribution surrounding the observer. Two experimental approaches are under consideration.

1. The development of a stable gravimeter to measure annual, and possibly epochal, variations in g , the gravitational field at the surface of the earth. The experiment was described in Quarterly Progress Report No. 77 (page 59). The measurements of g will depend on geophysical factors that must be crosscorrelated to the gravimeter output. Progress in the development of the instrument itself has been disappointing. The main difficulty lies in the geometry of the plate, which is levitated to achieve an unambiguous relation between the Stark transition frequency observed in the molecular beam and the force on the plate. Measurements performed with the originally proposed plate configuration give the ratio

$$\text{Force/Frequency} = K \left(1 + a \frac{d}{d_0} \right),$$

where d is the plate spacing, d_0 the fiducial separation. The coefficient $a \sim 10^{-3}$, which is due to the fringing field, is too large by a factor of 100 to allow use of this plate configuration in the experiment. Other plate configurations have been considered, and some of them look promising. Work on the gravimeter has been temporarily suspended.

2. A more direct experiment to search for evidence of a scalar gravitational field is a test for a violation of the strong principle of equivalence. If gravitational and atomic oscillators are placed in an artificial satellite, with the entire system put into free fall toward the sun, the period of one oscillator relative to the other would change by an amount

$$\frac{\Delta\tau}{\tau} \approx \frac{GM_s}{Rc^2},$$

where M_s is the mass of the sun, R the distance between the satellite and the sun, and $\Delta\tau/\tau \sim 10^{-8}$ at 1/10 A. U. Work has begun on the design and construction of an electrostatically suspended torsional gravitational oscillator which is insensitive to tidal forces.

Experiments in gravitation tend to engender advances in instrumentation. An adjunct to the gravimeter program was the development of a long-term stable Earth strain seismometer to try to measure radius changes of the Earth. The basic problem here appears to be the inadequate long-term stability of existing lasers. One of the major efforts of the research in this group is the frequency stabilization of a laser with an optical resonance as observed in an atomic beam used as reference. This has been discussed in Quarterly Progress Report No. 80 (pages 22-23). Since then, several matches between

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existing laser lines and optical resonances that could be observed in atomic or molecular beams have been uncovered. Construction of an atomic-beam magnetic-resonance apparatus has just been completed to exploit a match between an Argon laser line and a magnetic dipole transition in Rubidium.

R. Weiss

A. EXPERIMENTAL TEST OF THE FREUNDLICH RED-SHIFT HYPOTHESIS

A laser interferometer sensitive to 5×10^{-9} of a fringe shift has been employed to test the Freundlich photon-photon scattering hypothesis. This hypothesis was designed to give an alternative explanation to the observed Hubble "red shift" of the galaxies, which is usually attributed to a recessional Doppler shift. Our experiment, which will be published in the Physical Review, showed that 6328\AA photons suffered a $\Delta\nu/\nu < 2 \times 10^{-19}$ frequency shift on traversing an X-band radiation field of 3×10^{16} photons/cm³, 100 cm long. The Freundlich hypothesis would have anticipated $\Delta\nu/\nu \sim 10^{-14}$ for a 3°K cosmic black-body temperature.

G. Blum, R. Weiss

B. MEASUREMENT OF METASTABLE VERSUS GROUND-STATE ELECTRON EXCHANGE CROSS SECTIONS FOR HELIUM AND NEON

In connection with our program on laser frequency stabilization using an atomic beam as a primary frequency reference,¹ measurements of metastable vs ground-state

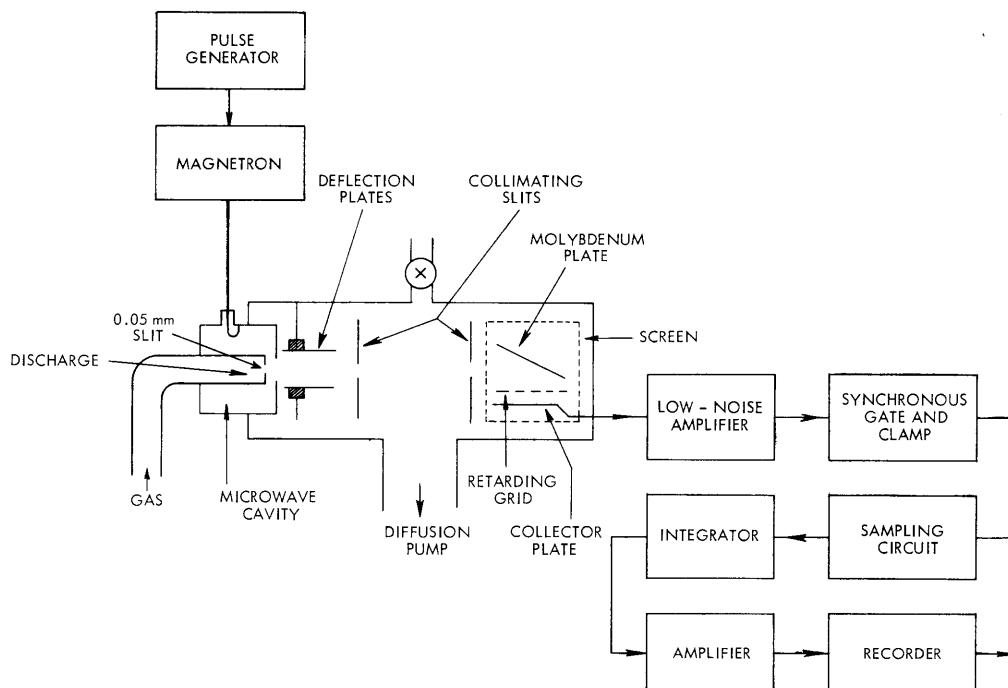


Fig. XI-1. Atomic beam apparatus.

electron exchange cross sections for Helium and Neon have been carried out.

The atomic beam apparatus is shown in Fig. XI-1. Metastables of Helium and Neon are formed in a short discharge tube inside an X-band cavity driven by a QK61 magnetron. Ground-state and metastable atoms effuse through a slit, 0.05-mm wide \times 4 mm high \times 0.25 mm thick, formed by cementing two soft glass microscope slides onto a soft glass tube with solder glass. Charged particles that come out through the slit are swept out of the beam by deflection plates. Two suitably placed slits farther down the apparatus define the atomic beam. Metastables were detected by electron ejection on a molybdenum surface. The ejected electrons were collected by a stainless-steel plate connected to a low-noise, high-input impedance amplifier. A time-of-flight technique was used to separate metastables from the energetic UV photons coming out of the discharge tube. The discharge was pulsed at a rate of 1000 times per second with a pulse duration of 0.2 msec.

Figure XI-2 shows typical detector data obtained with Helium and Neon metastables.

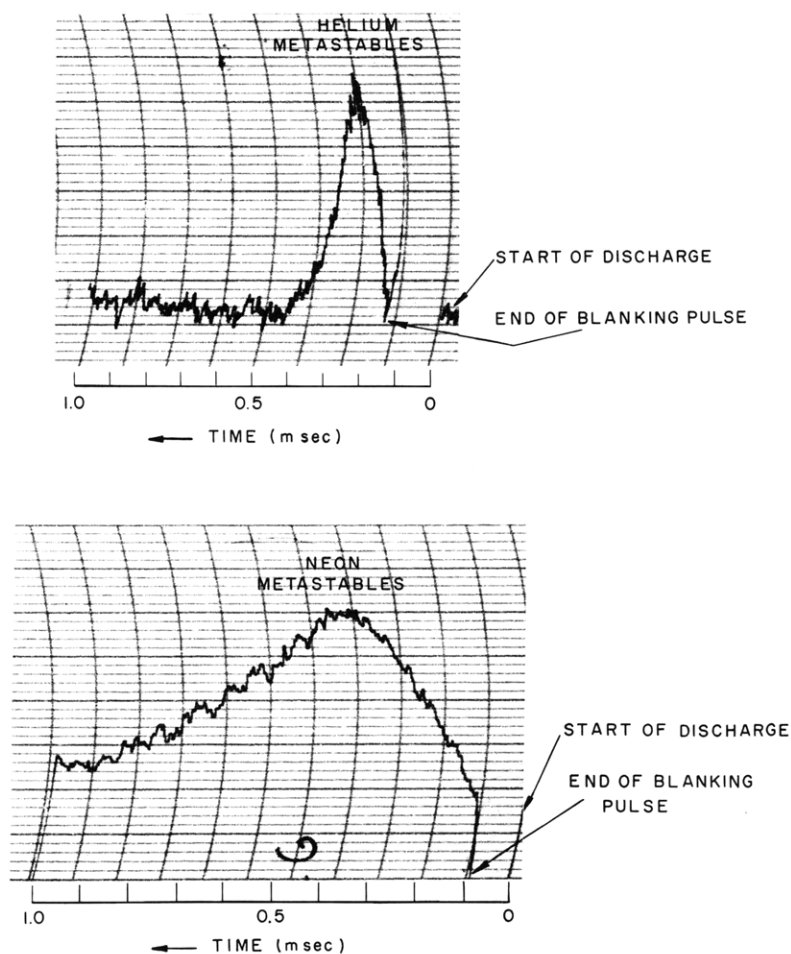


Fig. XI-2. Detector data obtained with the He and Ne metastables.

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Metastable vs ground-state electron exchange cross sections were determined by introducing ground-state atoms into the beam chamber and noting the attenuation in the number of metastables with increase in pressure in the chamber. A plot of \log_e (intensity of metastables received at the detector) vs apparatus pressure is shown in Fig. XI-3.

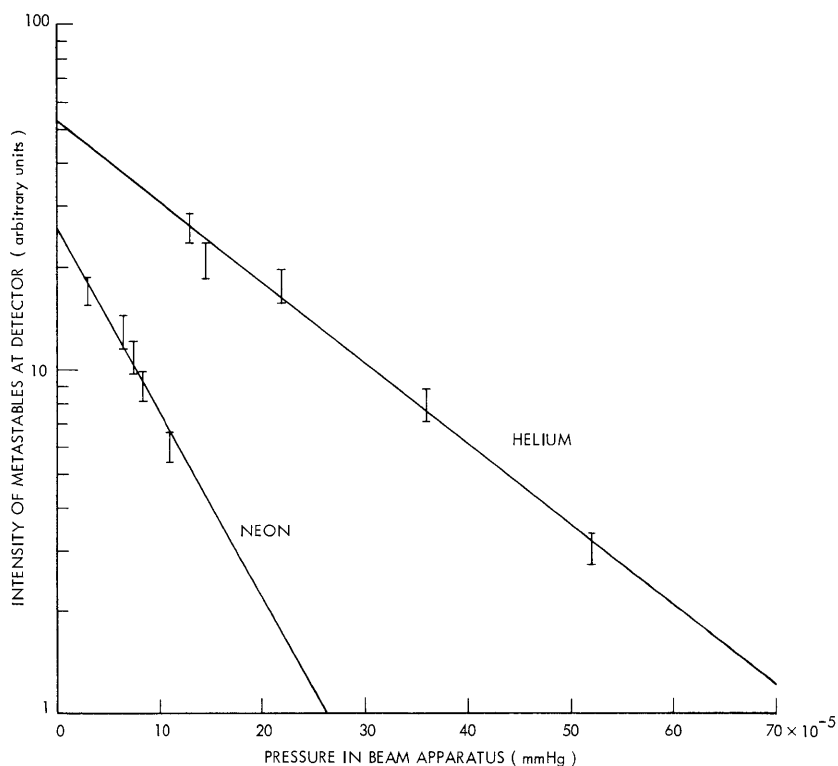


Fig. XI-3. Plot of \log_e (intensity of metastables received at the detector) against apparatus pressure.

The cross sections were found to be $6.8 \times 10^{-15} \text{ cm}^2$ for Helium, and $1.6 \times 10^{-14} \text{ cm}^2$ for Neon. The peak number of metastables leaving the discharge tube was estimated to be 2×10^{12} per second at a discharge pressure of 1.3 mm Hg for Helium, and 6×10^{12} per second at a discharge pressure of 0.8 mm Hg for Neon. The ratio of metastables to ground-state atoms leaving the discharge was 1×10^{-5} for Helium, and 8×10^{-5} for Neon.

In these measurements no effort was made to separate the $2s^3S$ and $2s^1S$ metastable states in Helium, and the $1s_5$ and $1s_3$ metastable states in Neon. An optical absorption was observed, however, in Neon $1s_5$ which could be used in discriminating the Neon $1s_5$ from $1s_3$.

S. Ezekiel

References

1. S. Ezekiel and R. Weiss, "Long-Term Frequency Stabilization of a Laser Employing a Molecular or Atomic Beam as Primary Frequency Reference," Quarterly Progress Report No. 80, Research Laboratory of Electronics, M. I. T., January 15, 1966, pp. 22-23.

