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CORNELL UNIVERSITY

Center for Radiophysics and Space Research

ITHACA, N. Y.

CRSR 511

Final Report

to the

National Aeronautics and Space Administration

NASA Contract NGR-33-010-139

FAR INFRARED ASTRONOMY

November 1, 1970 through March 31, 1972

Principal Investigator - J. R. Houck

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ABSTRACT

The research conducted under NASA contract NGR-33-010-139 is described. Two liquid helium cooled infrared spectrometers were designed and built. The first, has a Cassegrain optical system and a variable focal length between 20.25" (51.4 cm) and 36.45 (92.6 cm). It is capable of a resolution of 500. The second, has a focal length of 7-1/2" (19.1 cm) and has a resolution of 100. Both spectrometers have been operated at 10-30μ. Sample spectra are included.

I. Cassegrain Spectrometer

The guidelines that were followed in designing the spectrometer were as follows.

1. Wavelength range $1 \leq \lambda \leq 100\mu$
2. Resolution: $500\text{-}1{,}000 = \Delta\lambda/\lambda$
3. Sensitivity: As high as possible, preferably photon noise limited.
4. Ease of Operation: The spectrometer is to be used on a ground based telescope. It should be capable of operating with the C-141 airborne telescope.
5. Date Reduction: Preference should be given to systems requiring only limited data analysis.

At the time the proposal was written, a Michelson interferometer seemed to be the best choice. However, extended discussions with Michelson users convinced us that the problems of mechanical stability at $\lambda \approx 10\mu$ are very severe. At the time the proposal was accepted by NASA, a type of compact Littrow grating monochromator had been designed. The optical layout is shown in Figure 1. The instrument consists of a small Cassegrain collimator-telescope and a standard Bausch and Lomb diffraction grating. By operating the grating in the Littrow mode and using Cassegrain optics, a very compact unit results. The spectrometer has been fabricated and is shown in Figure 2. It is 10" long, 5" diameter and weighs 4 pounds including optics and detector.

The sensitivity of the system is limited only by the photon noise in the input beam since the entire spectrometer is designed to operate at $4^{o}K$. In this mode of operation, the sensitivity of the system will be fully equal to that of a Michelson interferometer. The spectrometer accepts all of the light in a 3 mm diameter aperture in the focal plane of the telescope. This corresponds to 15-30" for most ground based telescopes and is adequate for most observational programs.

After completion of the building phase, the spectrometer was modified by Dr. Carl Frederick to be used on the NASA Leased Lear Jet. His first series of field tests, 4-22 September 1972 showed that the instrument functioned well although difficulties with the aircraft prevented a full test of its sensitivity.

II. Liquid Helium Cooled Ebert Spectrometer

Many observations require less resolving power than is produced by the long focus Cassegrain system. These observations include observation of planetary atmospheres (where pressure broadening considerably broadens emission and absorption lines) and faint sources which are inexcessible to the high resolution instrument.

A drawing of the spectrometer is shown in Figure 2. As shown two detectors are used. Detector #1 is sensitive to radiation in the 16-28μ band. Detector #2 covers the 20-40μ band. In this configurattion Detector #1 (Ge:Cu) operates in first order. Detector #2 (Ge:Zn) simultaneously operates in second order. Order separation is accomplished by an interference filter operating in conjunction with a reststrahlen mirror. In this configuration the spectrometer will be used to make measurements of the atmosphere of Jupiter in the 16-40μ band. As shown by J. B. Pollack emission measurements made in this band can be used to determine the mass ratio of H_2/He in the planetary atmosphere.

The spectrometer can also be operated with two Ge:Cu detectors both operating in first order. By using two detectors the observation time can be cut in half. More detectors could be used, however, the signal processing becomes increasingly complex.

Figure 3 shows a spectral scan of a 500°C blackbody with and without an 0.002" Mylar film in the beam. The entrance aperture was 3.5 mm in diameter so the spectral resolution is degraded by approximately a factor of 3.

Figure 4 shows a spectral scan of the Orion Nebula taken with a 3.5 mm entrance aperture. The data shown has not been normalized for the instrumental response (Figure 3). All of the data was collected on a single Lear Jet flight on 16 November 1972.

The spectra in Figures 3 and 4 were taken using a single Ge:Cu detector which was made here at Cornell.

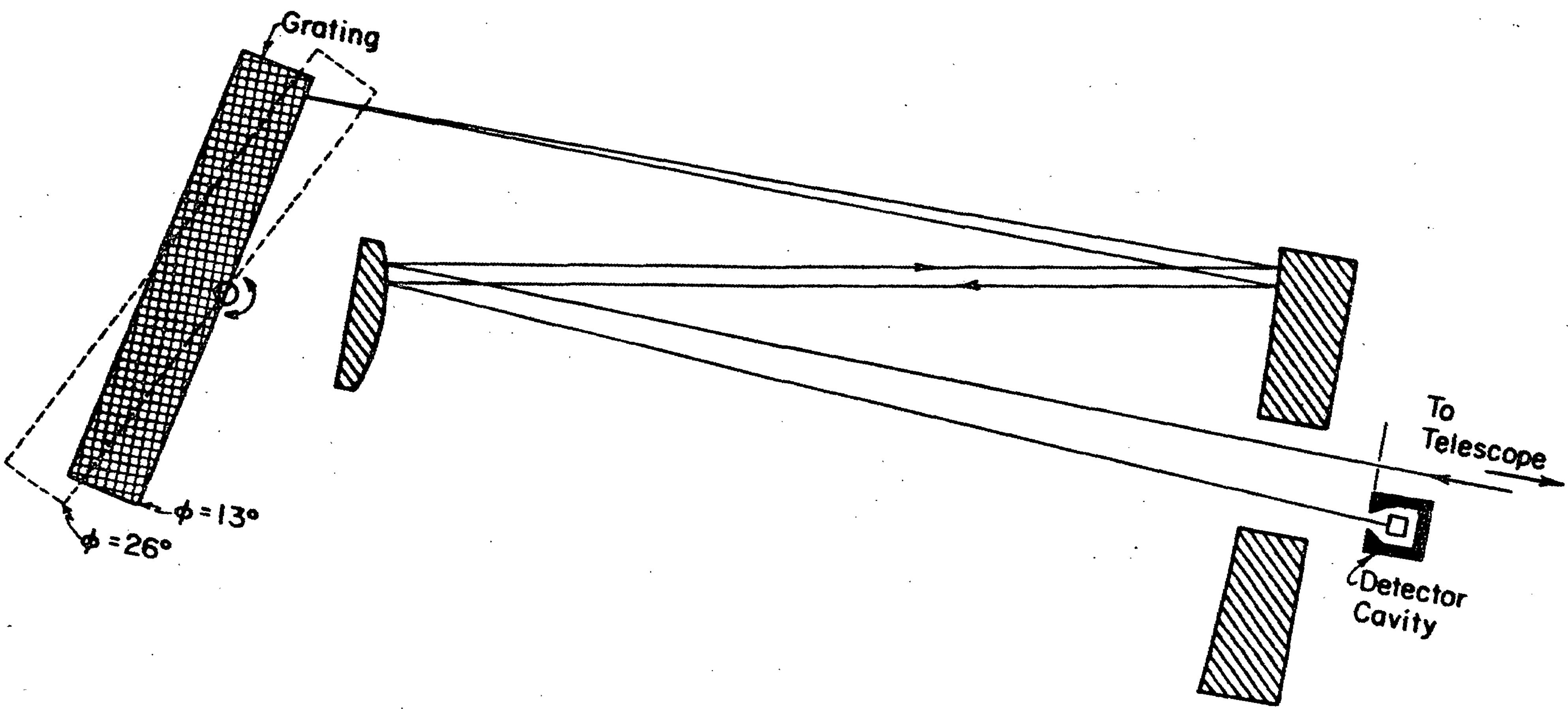
FIGURE CAPTIONS

Figure 1. A schematic view of the liquid helium cooled Cassegrain spectrometer is shown. The spectrometer has a resolution $\lambda/\Delta\lambda = 500$ at 10μ.

Figure 2. A schematic view of the liquid helium cooled Ebert spectrometer is shown. The spectrometer has a resolution $\lambda/\Delta\lambda = 100$ at 15μ.

Figure 3. A spectral scan of a $500^{o}C$ blackbody with and without a 0.002" Mylar film. The scan was made with the instrument shown in Figure 2. A 3.5 millimeter entrance aperture was used which degraded the instruments resolution to ~ 30.

Figure 4. A spectral scan of the Orion Nebula taken with a 3.5 mm entrance aperture and a resolution of ~ 30.



Scale: 1/1

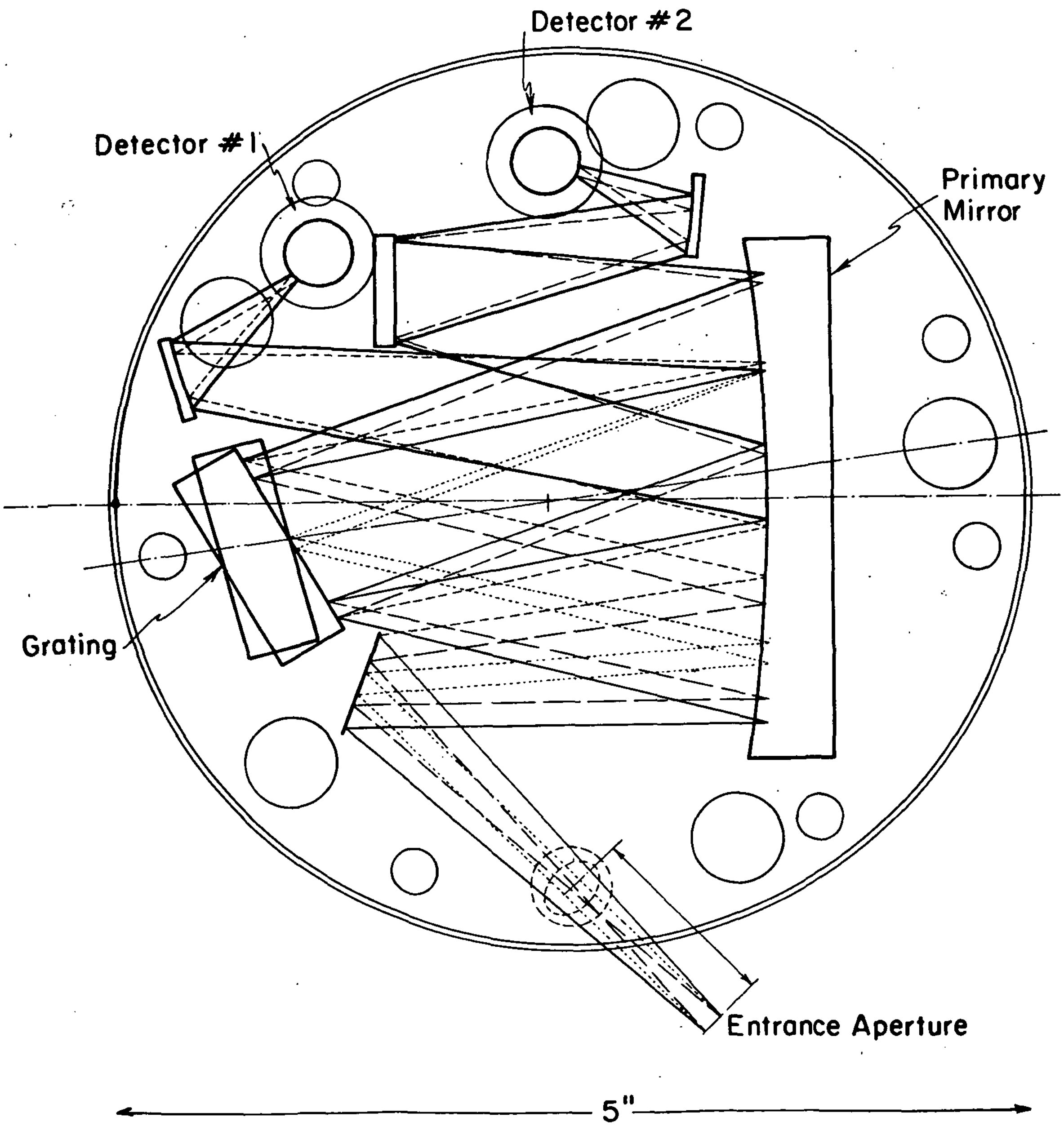
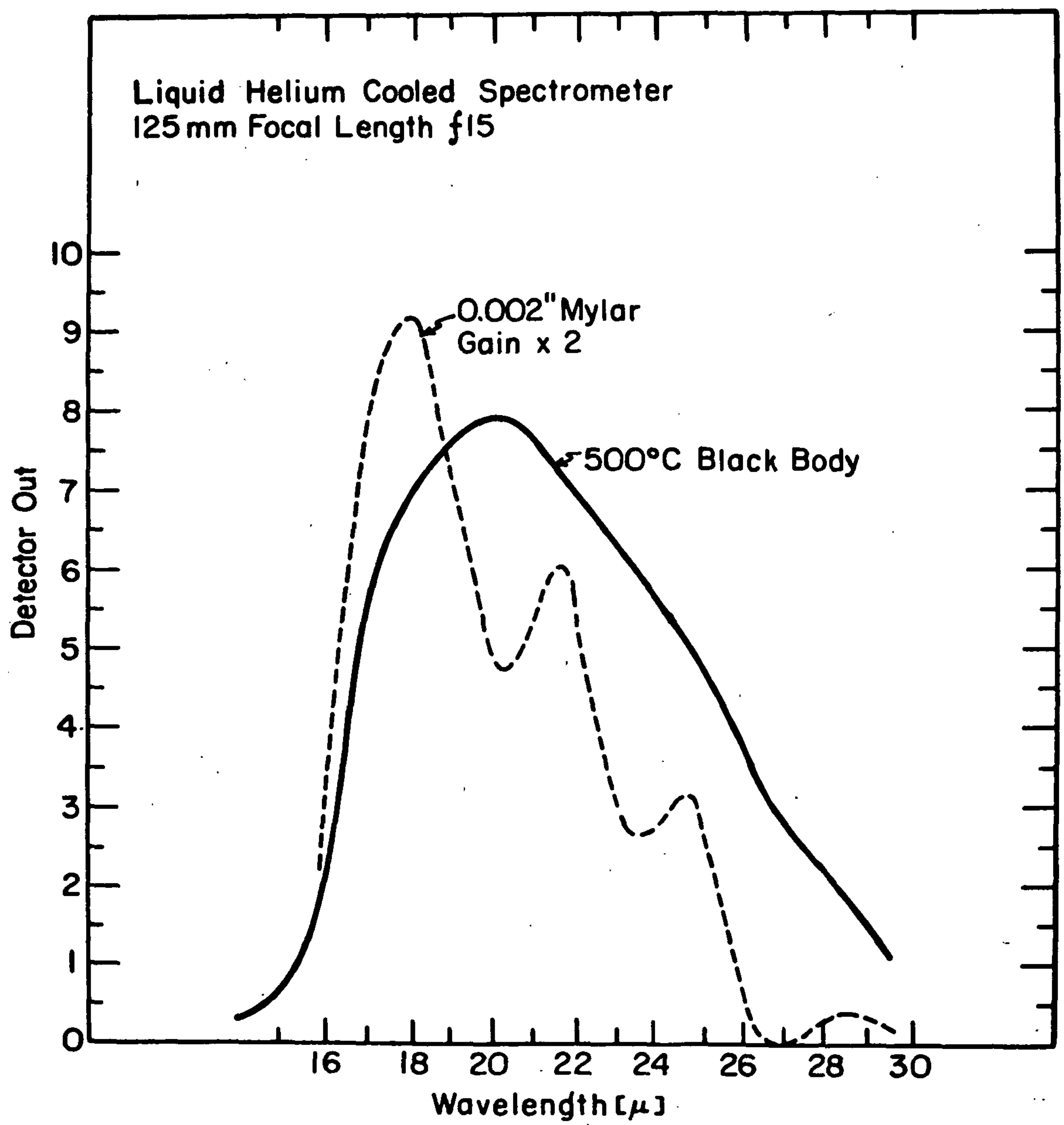

Detector #2
Detector #1
Primary Mirror
Grating
Entrance Aperture
5"

Figure 2.



Liquid Helium Cooled Spectrometer
125 mm Focal Length f15
0.002" Mylar
Gain x 2
500°C Black Body
Detector Out
Wavelength [μ]
0
1
2
3
4
5
6
7
8
9
10
16
18
20
22
24
26
28
30

Figure 3.

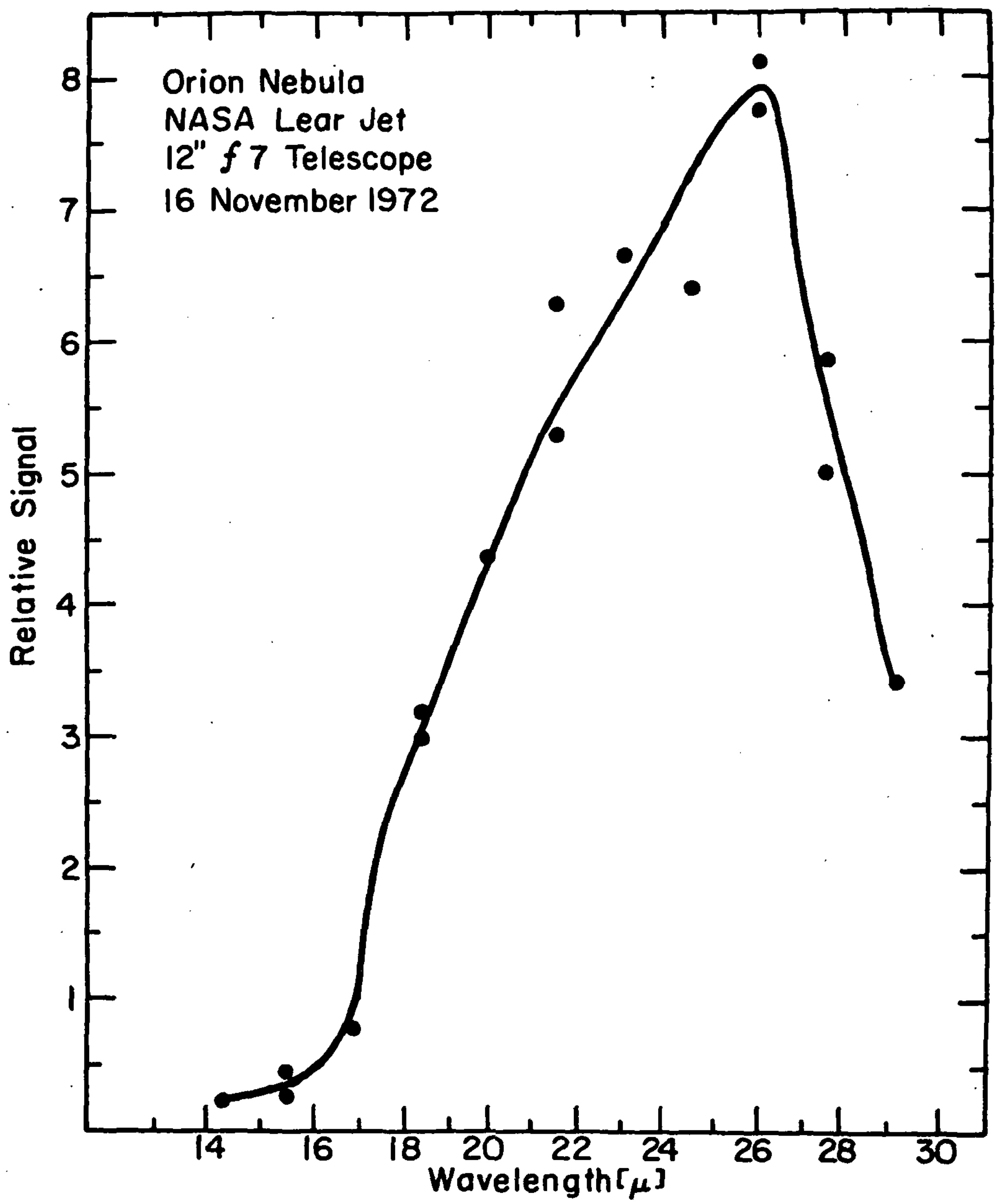

Orion Nebula
NASA Lear Jet
12" f 7 Telescope
16 November 1972
Relative Signal
1
2
3
4
5
6
7
8
14
16
18
20
22
24
26
28
30
Wavelength[μ]

Figure 4.