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LOW-BACKGROUND FAR-INFRARED TELESCOPE FOR BALLOON-BORNE INFRARED ASTRONOMY

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ABSTRACT

The design and performance of a new type of far-infrared telescope is discussed. The instrument is only 20cm in diameter, but its performance exceeds that of other telescopes at 100μ.

The performance of far-infrared telescopes is limited not only by size but also by design and environment. The 30cm infrared telescope flown in the Nasa-Ames Lear Jet (Aumann, Low and Gillespie 1970) was limited by the large background originating from the atmosphere at 50,000 feet and from the telescope itself. The work of Hoffmann and his group has indicated that sky background levels of 1 or 2% are possible at balloon altitudes. We therefore undertook to design an instrument whose internal background would be small enough that its performance would be limited primarily by the atmospheric background at balloon altitudes.

Figure 1 shows the principal features of the off-axis (Herschelian) design. The single 20cm diameter mirror is gold-coated to achieve an emissivity at 100μ less than 1%. Note also the baffle surrounding the mirror. Its emissivity is also about 1% and it insures that the detector sees only the sky after a single reflection.

Not shown in Figure 1 but essential to the operation of this system is the dewar window. This consists of a Mylar membrane only 4μ in thickness. At low altitude it is protected from ambient pressure by a housing which is removed at altitude. These windows produce negligible background and have proved quite reliable when used in this manner.

Within the dewar a 3mm diameter composite silicon-germanium bolometer (Infrared Laboratories, Inc., Tucson, Arizona) is mounted at the focus of a crystalline quartz field lens which images the detector onto the primary mirror. The cold far-infrared filters follow the design described by Armstrong and Low (Armstrong and Low 1973; Armstrong and Low 1974).

Table 1 summarizes the specifications of the telescope system. It should be noted that at altitude the background loading of the bolometer was insignificant and the performance was determined essentially by detector noise alone. This indicates that further improvements in sensitivity are possible.

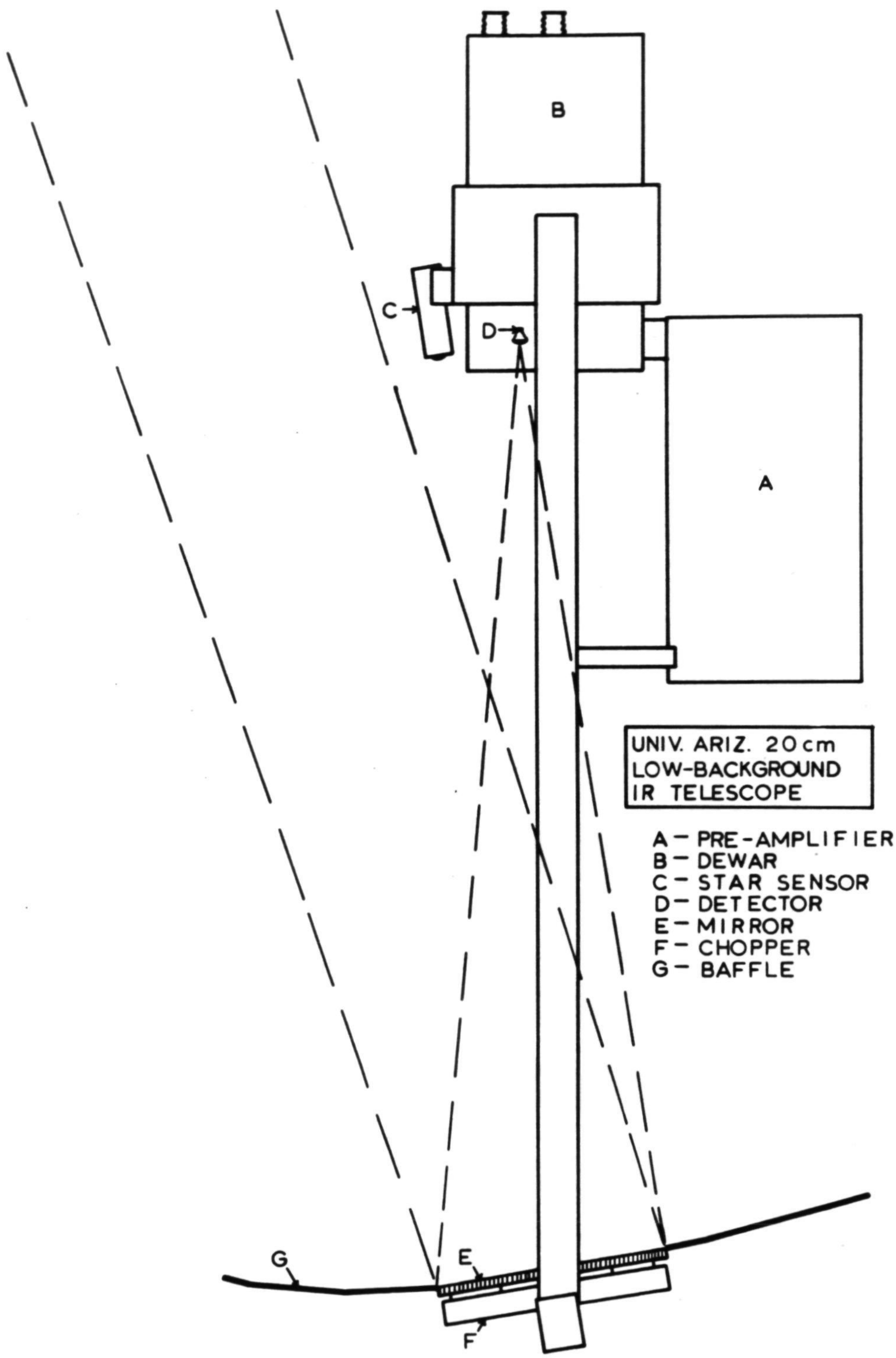

Figure 1. Principal features of the off-axis (Herschelian) design.

Specifications

Mirror dia. = 20cm
Beam dia. = 15'
Chopper throw = 15'
Chopper freq. = 7.6 Hz

Instantaneous sensitivity = 400 Jansky(10^{-26}w/M^2/Hz P.T.P., 1 sec)

Weight

Scientific payload	- 235 lbs.
Instrumentation + tel.	- 119 lbs.
32' parachute	- 54 lbs.
Ballast, crush pad, etc.	- 65 lbs.
500,000 $ft.^3$ balloon	- 194 lbs.
TOTAL	- 667 lbs.

Total power consumption = 15 watts
Chopper power = 2 watts
Flight altitude - 90,000 ft. MSL

Table 1

The 3-axis mounting is shown in Figure 2. The polar axis is oriented by means of a magnetically controlled azimuth stabilization system. An optical encoder permits read-out of the declination and hour angle in steps accurate to better than 0.1°. With this system it is possible to track celestial objects in a manner quite analogous to conventional ground-based telescopes. Long integration times are possible. It should be noted that the instrument itself is extemely lightweight and can easily be taken to much higher altitudes to achieve even lower background levels.

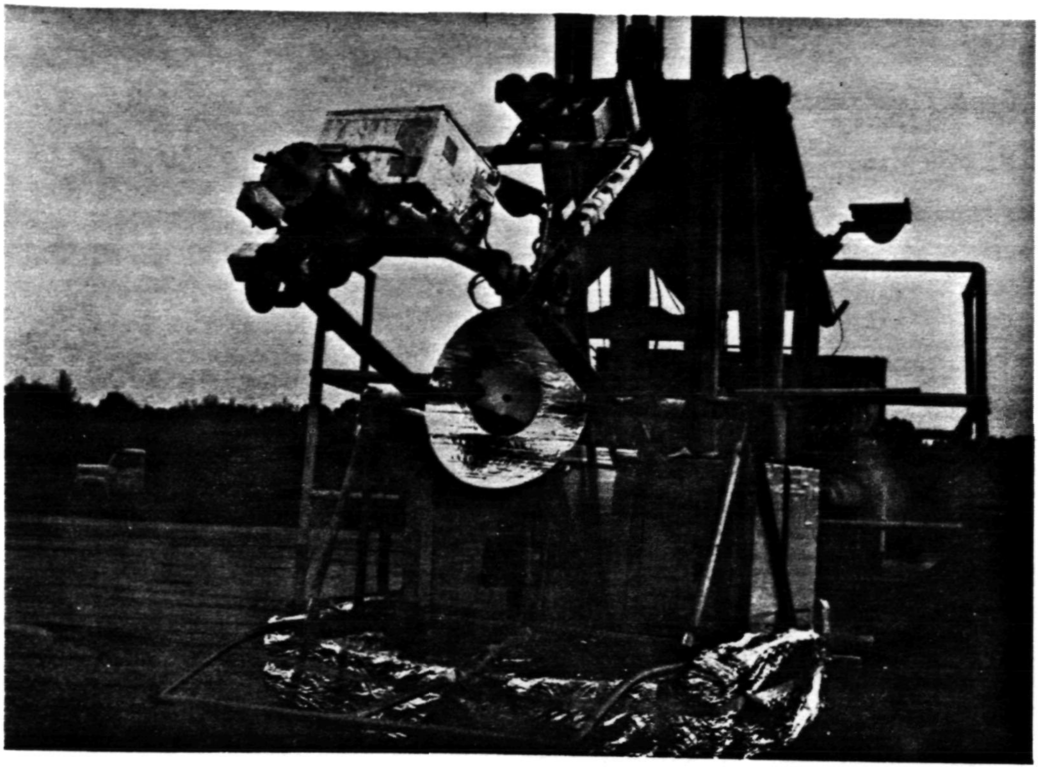

Figure 2. 3-axis mounting.

This system was flown from Palestine, Texas on two successful flights in January, 1974. Mars and Saturn were used as calibration sources and observations were made of HII regions W 3, Orion A, NGC 2024, and the bright infrared galaxy M 82. We believe this is the first detection of an extra-galactic source by a balloon-borne telescope. Preliminary data reduction shows a 100μ flux density for M 82 of about 1000 Jansky, in agreement with the results published by Harper and Low using the Lear Jet system (Harper and Low 1973).

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DISCUSSION SUMMARY — PAPER 2.9

Stabilization of this system utilizes a "dumbell" shaped inertia bar for the azimuth torque motor to work against. Two schemes were tested for coupling to the balloon. Both worked equally well. It was found that within a few arc-minutes of pointing accuracy, motion of the balloon has no effect.

Corrections to the observations were made to compensate for changes in the magnetic field, latitude and longitude caused by the balloon shift. In this way source positions were known to better than one tenth degree.

This system was used for observations of W-3, Orion, NGC 2024, M 82, Mars and Saturn. The flux observed for M 82 was approximately 1,000 to 1,200 flux units.