CONTINUED DEVELOPMENT AND APPLICATION
OF FAR-INFRARED DETECTION TECHNIQUES

Final Report

June 1, 1973 to May 31, 1974

University of Arizona
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I. Introduction

This report covers one year of an ongoing program of astronomical research in the far infrared. During this year most of our effort was directed toward the development of a balloon gondola and pointing system which can be used with the low background far infrared telescope developed during the previous year. That instrument was successfully flown during January 1973 using a gondola developed at M.I.T. by Dr. Walter Lewin's group. In the following we will describe our new gondola and review the progress made on flights carried out this year.

II. A Lightweight 3-Axis Pointing System and Gondola

Following two flights with the M.I.T. 2-axis alt-azimuth gondola and one test flight with a light weight version of their gondola which we constructed, we decided to build a 3-axis system which would provide much greater capabilities. In this design both a polar and declination axis are used; they are maintained in the proper orientation by a free hanging (vertical) azimuth shaft. As before the azimuth stabilization is by means of a servo system which senses magnetic north. Here, however, the single flux-gate magnetometer remains fixed since the polar shaft must always be pointed north. Accurately controlled and measured motion of the polar and declination shafts permit pointing in celestial coordinates, and the sky no longer rotates with respect to the IR telescope and its spatial modulator, as in the alt-azimuth system.

The following table summarizes most of the important parameters of this system. It should be noted that because of the light weight extremely small balloons are used, leading to a very modest cost per flight. The goal was to build a system which has accurate pointing capability coupled with higher through-put and sensitivity than was possible in the Lear Jet system. Like the Lear Jet we desire low cost and quick turn-around between flights.

Important Parameters of the System

IR Telescope:

Mirror Dia. = 20 cm
Beam Dia. = 15↑
Chopper Throw = 15↑
Chopper Freq. = 7.6Hz
IR Bandpass = 45 to 300μ
IR Background ≈ .02 of 220°K ambient blackbody
Instantaneous Sensitivity = 400 Jansky (10^{-26} W/m^2/Hz, P. to P., 1 sec)

Pointing System:

Hour Angle Motion = 0.5° steps
Range = ± 4 hrs.
Readout = 0.5° steps ± 1↑
Declination Motion= 0.1° steps
Range = -45° to + 75°
Readout = 0.1 steps ± 1↑
Azimuth Stability
Long Term ≈ ± 2↑
Short Term ≈ ± 2↑ to >15↑

Gondola:

Weight
Scientific Payload = 210 lbs.
NCAR Telm. & Comm. = 90 lbs.
32' Parachute = 54 lbs.
Crush Pad, Cut-down Pk., Ballast Hopper = 65 lbs.
Ballast = 25 lbs.
500K ft^3 Balloon = 194 lbs.

Total Launch Weight = 638 lbs.

Power Consumption

Scientific Payload = < 15 watts
Tel. & Comm. = 15 watts

Flight Altitude = 90,000 ft.

Tel. & Comm.

No. of Data Chans = 10
No. of Commands = 18

III. Flight Results

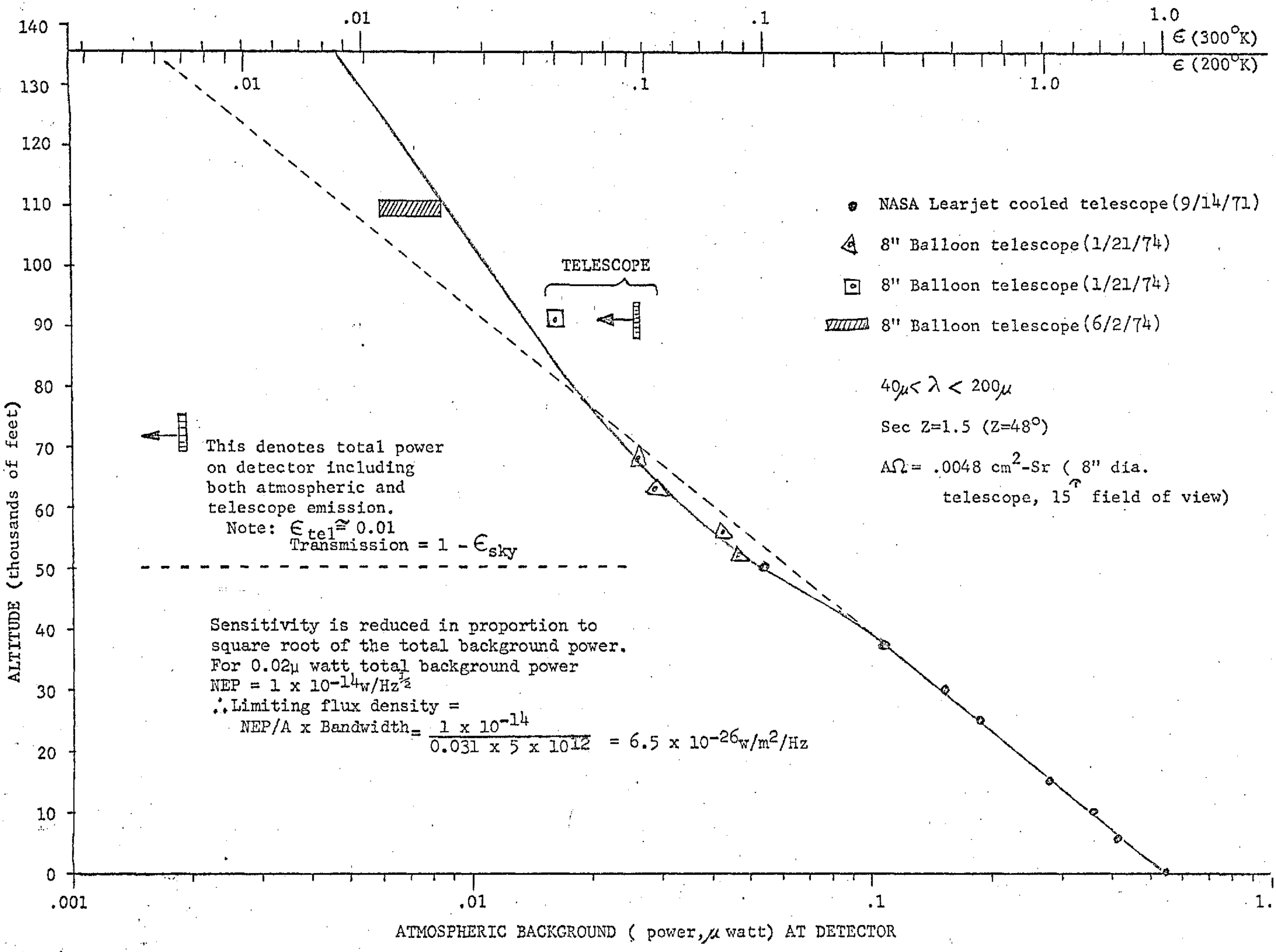
The first flights of the new system were carried out in January 1974 at Palestine, Texas. The first flight was of surprisingly brief duration due to unexpectedly high winds at altitude. In three hours of operation it was determined that the entire system functioned properly, except for a small problem in the declination drive, and that the sensitivity was reasonably near the expected value. Orion was the only source observed. It was also shown that the infrared offset problem experienced in earlier flights have been only partially corrected. Sky brightness measurements were made and it was noted that although the azimuth stabilization system produced a high degree of stability during most of the flight, there were periods of instability of variable amplitude and duration. It was an exceptionally successful first flight.

Fortunately, the gondola was recovered in good condition and prepared for the second flight, which took place nine days later. On this flight the winds at altitude had nearly stopped and the gondola moved less than 100 miles during the 10-hour flight. The system behaved properly with no declination problems and a number of observations were obtained. Saturn and Mars were observed as calibration sources. Observations were made of Orion, NGC 2024, W3 and the bright infrared galaxy M82. The earlier detection of M82 by Harper and Low using the 12-inch Lear Jet telescope was confirmed at a flux level of about 1000 flux units. Because a more accurate alignment procedure was used prior to this flight a significant improvement was made in the infrared offset.

Because of the light winds during the second flight, the instrument was only 100 miles east of Palestine and still under local control just before sunrise. We decided to carry out an experiment in which the data were recorded during descent.

We were thus able to obtain sky brightness observations from 90,000 feet down to an altitude of 50,000 feet. These sky brightness data have been compiled with data from other flights and with similar though independent measurements made with the Lear Jet. The attached graph summarizes these results.

As in the first flight, periods of instability of the azimuth control system were experienced. It was determined that the system behaves differently when suspended from the balloon at altitude than in any suspension system that could be erected on the ground. We therefore undertook a test flight in which the infrared telescope was removed and instrumentation was added which would give us detailed information concerning a number of important parameters of the system. For example, we were able to measure the angular rotation of the torque bar on which the azimuth control motor reacts. We were also able to measure pendulous motion of the gondola directly. Much valuable engineering data was obtained during this brief test flight in April.



140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ALTITUDE (thousands of feet)
.01
.1
1.0
ϵ (300°K)
ϵ (200°K)
.01
.1
1.0
TELESCOPE
NASA Learjet cooled telescope (9/14/71)
8" Balloon telescope (1/21/74)
8" Balloon telescope (1/21/74)
8" Balloon telescope (6/2/74)
40μ < λ < 200μ
Sec Z=1.5 (Z=48°)
AΩ = .0048 cm²-Sr (8" dia. telescope, 15' field of view)
This denotes total power on detector including both atmospheric and telescope emission.
Note: ϵ_tel ≅ 0.01
Transmission = 1 - ϵ_sky
Sensitivity is reduced in proportion to square root of the total background power.
For 0.02μ watt total background power
NEP = 1 x 10^-14 w/Hz^½
∴ Limiting flux density =
NEP/A x Bandwidth = 1 x 10^-14 / (0.031 x 5 x 10^12) = 6.5 x 10^-26 w/m²/Hz
.001
.01
.1
1.
ATMOSPHERIC BACKGROUND (power, μ watt) AT DETECTOR

List of References

"Far Infrared Observations of Galactic Nuclei", The Astrophysical Journal 182, L89-L93, 1973, D.A. Harper and F.J. Low.

"New Techniques for Infrared Filters", Applied Optics 12, 2007, 1973, K.R. Armstrong and F.J. Low.

"Far-Infrared Filters Utilizing Small Particle Scattering and Anti-Reflection Coatings", Applied Optics 13, No. 2, 1974, K.R. Armstrong and F.J. Low.

"Observations of M17 from 10 to 100 Microns", 141st Meeting American Astronomical Society, D.A. Harper, G.H. Rieke and F.J. Low, 1973.

"Far-Infrared Observations of VY Canis Majoris", 141st Meeting, American Astronomical Society, N.W. Boggess, F.J. Low and D.A. Harper, 1973.

"Far-Infrared Radiometry From a Balloon-Borne Telescope", 141st Meeting, American Astronomical Society, G.R. Ricker, W.H.G. Lewin, W.M. Poteet and F.J. Low, 1973.

"Low-Background Far-Infrared Telescope for Balloon-Borne Infrared Astronomy", Symposium on Telescope Systems for Balloon-Borne Research, Nasa-Ames, F.J. Low, W. Poteet and R. Kurtz, 1974.

AMERICAN ASTRONOMICAL SOCIETY

Abstract submitted for the 141st meeting

Category 7, Date submitted October 9, 1973

Read by F.J. Low

Observations of M17 from 10 to 100 Microns.

D.A. HARPER, Yerkes Obs. & G.H. RIEKE, F.J. LOW, U. Ariz - The 30cm infrared telescope in the NASA Learjet was used to observe M17. A map with 2.2' resolution was made at 90μ and north-south scans with a 3' beam were obtained at 12 and 21μ. The extended source comprising the southern part of the nebula does not change size or structure over this range of wavelength. The central areas of both the northern and southern components of the H II region were also mapped with a 5".5 beam at 10.2μ from the ground; at this resolution only one relatively weak discrete source was found. This source lies near the center of the southern component and has a very deep silicate absorption at 10μ. These results taken together with the 21μ map of Lemke and Low (ApJ 177, L53, 1972) confirm the two dust component model proposed by them.

Frank J. Low

Signature of author

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AMERICAN ASTRONOMICAL SOCIETY

Astract submitted for meeting 141

Category 6, submitted 10/4/73

Read by N. W. Boggess

Far-Infrared Observations of VY Canis Majoris,

N. W. Boggess, NASA HQ., F. J. Low, U. Arizona, & D. A. Harper, Yerkes Observatory. -- The first observations of the irregular M variable VY Canis Majoris at wavelengths beyond 25 μm have been made using a 30-cm telescope open port aboard the NASA-Ames Lear jet. The observations, obtained on three lights, employed a 5' beam size and used a mult-band photometer with cooled filters having effective wavelengths of about 40 and 100 μm. Calibrations in flight were obtained from observations of the planets Saturn and Venus. The far-infrared flux near 40 μm was found to be 6×10^{-23} W/m^{2}Hz, and an upper limit near 100 μm of 1.4×10^{-23} W/m^{2}Hz. The total systematic errors in the fluxes are ± 20%.

The energy at these far infrared wavelengths may be assumed to originate ~~predominantly~~ entirely in the circumstellar shell. In order to derive separate temperatures for both the shell and the star the data were combined with observations at shorter wavelengths by A. R. Hyland et al (1967 Astrophys J. 158, 619) and F. J. Low et al (1970 Astrophys. J. 160, 531) which contain contributions from both shell and stellar radiations. The shell temperature is found to be 350° K which is comparable to temperatures found for the small infrared source. There is no evidence, however, for a larger thermal source corresponding to the large polarized nebula around the star observed by Herbig (1972 Astrophys. J. 172, 375) at optical wavelengths.

AMERICAN ASTRONOMICAL SOCIETY

Abstract submitted for the Tucson meeting

Category 7, Date submitted 9 October 1973

Read by G. R. Ricker

Far Infrared Radiometry from a Balloon Borne Telescope. G. R. RICKER and W. H. G. LEWIN, Center for Space Research, M.I.T., and W. M. POTEET and F. J. LOW, Steward Obs., U. of Arizona. - A low background balloon-borne telescope (20 cm aperature, $f/4$ Herschelian reflector) equipped with a liquid He-cooled germanium bolometer was flown to an altitude of $\sim$ 100,000 ft on 16-17 June 1973. The system passband was $50\mu \lesssim \lambda \lesssim 350\mu$. The field of view was 45 arc minutes. Results of a mapping of sources near the galactic plane in the region $348° \gtrsim \ell^{II} \lesssim 360°$ and flux measurements of the H II region W3 will be reported. Jupiter was observed for calibration purposes.

Special Instructions:

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