mark a front in an advancing ocean floor pushing ahead an older, less magnetic sea floor. If we assume a spreading rate of about 1 cm/year (*8*) and assume this to be uniform and constant [although we are aware that this is a hazardous assumption (*9*)], we can extrapolate the age of this front as 200 to 250 million years, or Middle Triassic to Middle Permian. This age appears to fit reasonably well with the inferred age and distribution of the seismic reflecting horizon B of Ewing *et al.* [The seismic reflecting horizon B is inferred to be of late Jurassic age (*5*).] Irving (*10*) reports a long period of about 50 million years (the Kiaman magnetic interval) during the late Paleozoic when the field was consistently of reversed polarity. When viewed in relation to spreading of the ocean floor, a long period during which no changes in magnetic polarity occurred should be manifested by a zone of smooth or undisturbed magnetic field. It is entirely possible, therefore, that the undisturbed magnetic zones lying toward the continental side of the boundaries shown in Fig. 3 represent the expression of an ancient sea floor formed during the late Paleozoic and that the boundary itself marks the approximate position of the isochron separating the Paleozoic and the Mesozoic eras. The possible relation of the magnetic quiet zone to the Permian has been independently proposed in a study by Windisch *et al.* (*11*) which incorporates magnetic and seismic profiler data. The smooth zone is roughly 400 km wide, and, if the zone does represent a period of no changes in magnetic polarity and if 1 cm/year is a good average spreading rate, then this width and rate establishes a minimum time of 40 million years during which changes in polarity did not occur. The observation is in agreement with Irving's results.

It is not yet clear whether the western magnetic boundary extends as far south as the points labeled *V-22* and *A-153* east of the Lesser Antilles arc. It is clear, however, that the distinct magnetic boundaries on both sides of the North Atlantic do not continue into the South Atlantic, but this is perhaps not surprising in view of the faster spreading rates deduced for the South Atlantic (*12*).

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Far-Infrared Surveys of the Sky

Abstract. *A series of far-infrared surveys of the sky is searching for thermal radiation from interstellar grains and for other localized sources of far-infrared radiation. A balloon-borne germanium bolometer, cooled by liquid helium, is used in associaton wth a telescope and spectral filters. During two initial flights the response to a black-body source was mainly between 300 and 360 microns. Approximately half the celestial sphere was surveyed, includng most of the northern Milky Way. The angular resolution was 2 degrees. Moon was the only source of thermal radiation detected. The upper limit on the differential flux, relative to background, from other sources was* 2×10^{-23} *watt per square centimeter per hertz, corresponding to an antenna temperature of 0.6°K in the Rayleigh-Jeans approximation, or 10°K for a black body.*

We report on the first two balloon flights of a series searching the sky for extended emission regions and bright point sources in the far infrared (25 μ to 1 mm); strong absorption by water vapor prevents study from sea level. Farmer and Key (*1*), studying the solar spectrum from a 5200-m mountain top, found no trace of solar emission between 40 and 300 μ, while the narrow peak found at 350 μ corresponded to about 5-percent transmission.

This spectral region of five octaves, almost entirely unexplored, is of interest for a variety of reasons. The unknown emission process giving rise to the continuum of the brightest quasar, 3C273, appears to peak here (*2*); in fact, most of the energy from 3C273 seems to be radiated in the infrared. At slightly shorter wavelengths other processes appear to give variable emission from regions surrounding red giant stars (*3*). It has been predicted (*4*) that the thermal radiation of interstellar grains may be observable in this region and probably not outside it.

Already-existing measurements can be used to provide an upper limit for the flux from possible objects radiating in this spectral region. Upper limits on the background flux at 340 and 560 μ have been derived from a study of interstellar molecular lines (*5*); the limits are 2.5×10^{-20} and 2.5×10^{-21} watt cm^{-2} hz^{-1} $steradian^{-1}$. Hence a single object outside the solar system, providing as much as 3×10^{-19} or 3×10^{-20} watt cm^{-2} hz^{-1} at these wavelengths, could have escaped detection by this method. Similar, perhaps slightly tighter but less convincing

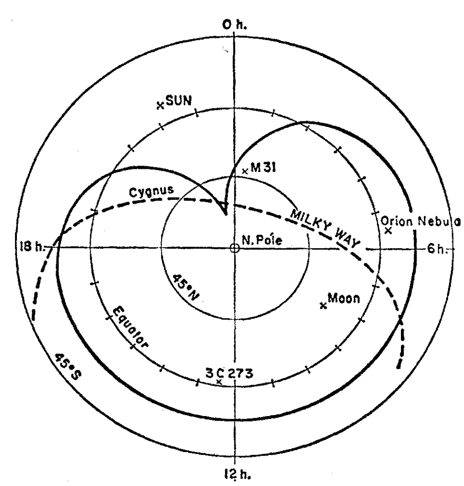

Fig. 1. The region of sky surveyed during the flight of 21 February 1967. Interesting features are indicated; Moon alone was detected.

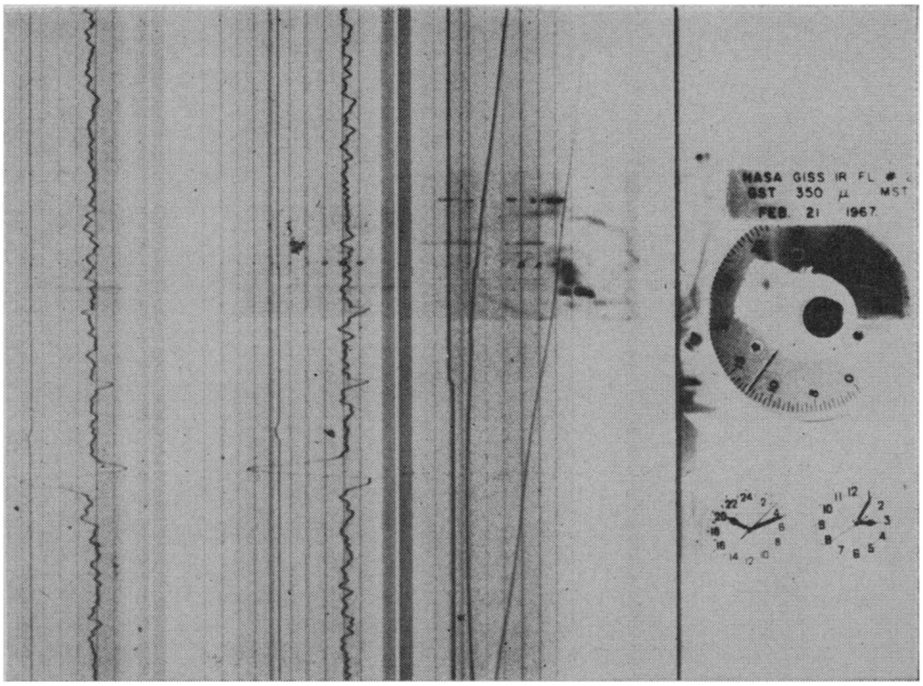

Fig. 2. An on-board record of observations of Moon at a wavelength of 320 μ. The traces are: channel 1 (left), detector output phase 1; channel 2 (center), detector output phase 2; channel 3 (right), the magnetometer outputs and a record of engineering data. At far right are a barometer and two clocks.

limits on the energy density in the galaxy at infrared wavelengths might be derived from the cutoff in the cosmic-ray electron spectrum. Since these limits are not very restrictive for the possible existence of localized bright sources in the far infrared, the balloon-borne telescope and radiometer were designed and built to search for such objects.

Because it was not known a priori how far fluctuating atmospheric emission might hinder observations from the stratosphere, initial observations were planned for a wavelength of 350 μ, at which there is a minimum in the water-vapor opacity and an expected atmospheric transmission exceeding 90 percent at balloon elevations. An angular resolution of 2° was chosen to give reasonable sensitivity both for extended objects like the Milky Way and zodiacal light and for sources of small angular diameter.

The radiometer is a germanium bolometer, cooled by liquid helium, (*6*) with a root-mean-square noise-equivalent power of 7×10^{-14} watt·sec$^{0.5}$ at a temperature of 1.8°K. The detector is fed by an $f/1.2$ crystal-quartz lens, with an aperture of 2.5 cm, that is inside the dewar. The filters are of fused quartz, black polyethylene, No. 80 wire mesh (used in transmission) (*7*), and thallium bromide at liquid-helium temperature (*8*). The spectral response of the system was checked with a laboratory thermal source and a variety of dielectric and wire-mesh filters.

The response to the thermal source appeared to be entirely in the band between 300 and 450 μ, peaking at 320 μ. The height of the transmission when the source was observed through additional mesh filters (69 percent through No. 100; 47 percent through No. 80) showed that the energy was mainly concentrated between 300 μ, the short-wave length cutoff of thallium bromide, and 360 μ, the wavelength at which the mesh filters have equal transmission. This band is distinctly narrower than that predicted from published data on the behavior of filter materials.

The incident beam is modulated by an aluminum mirror, outside the dewar, rotating at 8 cy/sec. The mirror's normal is set 0.5° away from the axis of the motor so that the mirror's motion wobbles the telescope beam around a circle 2° in diameter. Two optical pickups at the mirror give signals for phase-sensitive detection in two phases separated by 90°. This system then determines flux gradients in the sky in two directions at right angles, and is insensitive to constant and uniform instrumental, sky, and cosmic flux. The detector output is recorded on board by a 35-mm camera photographing meter pointers on continuously moving film. The mirror reflection of the beam is so oriented that the radiometer points at the sky 60° from the zenith.

The package is rotated in azimuth with respect to the balloon once every 8 minutes. Combined with Earth's diurnal motion, this rotation sweeps a large part of the celestial sphere during one 12-hour flight. The magnetic azimuth of the balloon is read by two flux-gate magnetometers; a sidereal clock is photographed every 90 seconds. During each successive 90-second interval, one of 12 measurements of voltage and temperature is recorded; once each 12th interval a thermal calibrator, giving a crude calibration corresponding to 35°K, is inserted in the beam.

On the first of two flights (*9*) for the 350-μ survey (from Palestine, Texas, 2 November 1966), sensitivity was severely reduced by interference from the balloon radio beacon that developed aloft. The second flight (from Page, Arizona, 21 February 1967) was fully satisfactory; the balloon reached an altitude of 29,890 m at 1725 M.S.T. and slowly descended to 27,140 m during the night; the package was parachuted at 0745 the following morning, landing near Kingman, Arizona. The area of sky surveyed (Fig. 1) covers more than 50 percent of the celestial sphere and most of the northern Milky Way.

During the flight the thermal radiation of Moon, which was almost at full phase, was detected. The observed flux and angular resolution of the instrument are compatible with Moon's expected effective temperature of 300°K at this wavelength and phase, and with high atmospheric transmission. This observation of Moon is believed to be the first in this wavelength band. The flight record corresponding to one of three observed lunar transits appears in Fig. 2; since Moon fills only 1/16 of the telescope beam, the signal corresponds to about a 20°K gray-body "antenna" temperature; the root-mean-square noise is about 0.6°K for a 1-second integration time.

No source was detected other than Moon. This result places an upper limit on the flux from the interstellar grains, other localized celestial sources, and stratospheric "cloudiness." Since the instrument was designed to be insensitive to uniform background radiation, no limit on the absolute atmospheric or cosmic flux can be given. Stratospheric cloudiness was not detected. The records corresponding to the directions of the brightest stars of various types, of radio sources of different kinds, and of the lane of dark interstellar matter in Cygnus, the Andromeda galaxy M31, and the Orion nebula were all examined. The maximum possible flux in a 10^{-3}-steradian solid angle in the 300- to 360-μ band is 3×10^{-12} watt/cm^2, corresponding to an average of approximately 2×10^{-23} watt cm^{-2} hz^{-1}. A black-body (optically thick) source 2° or greater in diameter, yielding this flux, woud have a temperature of 10.0°K. For a warmer small or optically thin source providing as much radiation flux in the Rayleigh-Jeans tail of the Planck distribution, the apparent temperature averaged over the 2° width of beam would be 0.6°K.

One should note that the galactic center, Sun, the inner zodiacal light, and most of the planets were not observed during these first flights. However, no observational problems appeared after sunrise, so that all these observations seem possible. Indeed it was encouraging that no effects attributable to variable atmospheric emission were apparent at any time during flight. Further flights will be made at shorter wavelengths and with sensitivity increased by reduction in coverage of the sky.

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11. Work aided by NASA grants NGR 33-008-062 and NSG-445 to Columbia University. We thank the staff of the National Center for Atmospheric Research who flew the balloons, George Clark for advice on balloon equipment, and Robert Jastrow, director of the Goddard Institute for Space Studies, for encouragement.

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Interferometer Experiment with Independent Local Oscillators

Abstract. *We have operated an interferometer with independent local oscillators and without any communication link of wide bandwidth between the elements of the interferometer. This makes operation possible at very long base lines because, heretofore, construction of the communications link has been the factor limiting the separation of the elements. In our system, coherence at the two elements is maintained through the use of two highly stable, atomic oscillators. The intermediate-frequency output signals are recorded at each element on a high-speed digital tape recorder. Interference fringes are produced later by cross-correlating the two tape records in a digital computer.*

The history of radio interferometry is one of steadily increasing base lines to obtain ever higher angular resolution. The early interferometer experiments maintained coherence by the transmission, through cable, of a local oscillator signal to the two antenna elements from some central location and by the transmission of the two intermediate-frequency signals from the elements back to the central location for correlation (*1*). More recently, there was a need for longer base lines, and the cable system was no longer economical. A microwave transmission link replaced the cables, both for the synchronization of the local oscillators and for the transmission of the intermediate-frequency signals (*2*). Even this system, however, becomes uneconomical for base lines exceeding a few hundred kilometers, because of the line-of-sight requirement on the microwave link.

For very long base lines, the most economical and convenient means of transmitting the broad-band data is apparently through the use of magnetic tape recordings. The radio-frequency signals may be reduced to the frequency range recordable on magnetic tape either by detection (*3*) or by mixing with a local oscillator, which must be coherent between the two elements. The former method has an intrinsically lower signal-to-noise ratio by the factor of the antenna temperature to the system temperature of the radiometer, a very small number for most radio sources.

We have developed and operated an interferometer system which supplies the coherent local oscillator signals at each element by the use of two independent, highly stable atomic oscillators. Figure 1 shows a block diagram of the receiver. The 610-Mhz radio-frequency amplifier comprises two stages, consisting of a parametric amplifier followed by a transistor amplifier. Both signal side bands are heterodyned to the video passband 0 to 250 khz. The 610-Mhz local oscillator signal is provided by an oscillator in phase with the 122nd harmonic of the 5-Mhz stabilized output of the atomic oscillator. These atomic oscillators (*4*) consist of a high-quality crystal oscillator controlled in frequency by a comparison with the microwave line generated by atomic transitions in the rubidium gas.

The video signal is amplified and clipped, so that only the sign of the signal is preserved (*5*). This clipped waveform is sampled at a 720-khz rate, and the resulting bits are recorded on a high-speed digital magnetic tape drive. The sampling is controlled by the atomic frequency standard. The 5-Mhz standard also drives a digital clock, which is set by comparison with the Loran C 100-khz very-low-frequency transmission. The magnetic tape recordings are started by pulses provided every 10 seconds by the digital clock. Further synchronization is provided by writing a gap in the tape records every 0.2 second, so that a character dropped in the process of recording affects only a small part of the whole tape. In making our observations, we record the whole length of a tape on a source. This gives 200 seconds of data, totaling approximately 1.4×10^8 bits of information.

The tapes from the two stations are brought together in a digital computer. One record is delayed (shifted) by an appropriate number of bits, and one-bit multiplication is performed. The resulting product is integrated over an interval of 0.4 msec (288 bits). This compacted product is fitted by a sine wave, at the calculated interferometer fringe frequency, over the successive 0.2-second intervals between gaps in the tape record. The interferometer fringe frequency will not be known exactly, however, because of small fre-